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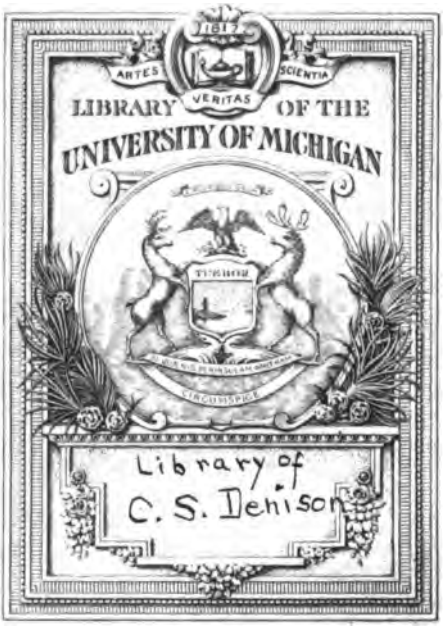
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THE WONDERS

OF

MODERN MECHANISM.

A RÉSUMÉ OF

RECENT PROGRESS IN MECHANICAL PHYSICAL, AND ENGINEERING SCIENCE.

BY

CHARLES HENRY COCHRANE,

Mechanical Engineer,

AUTHOR OF "ARTISTIC HOMES, AND HOW TO BUILD THEM," "THE HISTORY OF MARLBOROUGH," ETC.

ILLUSTRATED.

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1896.

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TO THE

ARMY OF AMERICAN INVENTORS,

WHO OCCUPY THE FIRST PLACE IN THE WORLD'S MARCH OF PROGRESS, THIS BOOK

IS

APPRECIATIVELY DEDICATED.

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PREFACE.

THE design of the writer of the following pages is to present to the public, in popular language, the results obtained within recent years by engineering and mechanical science, together with suggestions as to what the future may bring forth, such inferences being drawn from the known lines of research upon which great minds are bent. There exists an unfortunate tendency in the newspaper press, when publishing accounts of new inventions, to laud each one in accordance with some one's flights of fancy, claiming so much, and making so many exaggerated and unscientific statements, that careful readers have learned that they cannot depend upon the daily newspaper, as a rule, to give them an accurate record of the world's progress in mechanics and physical science. Among technical journals, on the other hand, there is frequently an equally unfortunate tendency to so hide the descriptions of present and coming inventions in a maze of technical detail that only a favored few can understand them. Between these two the writer has tried to steer his course, ever on the watch to maintain accuracy with plain and simple statement. If there are occasional lapses into technical language, varied by flights of speculation into the realms of the possible rather than the existent, it is hoped that the reader will pardon such sandwiching for the sake of the facts that lie between. For these no apology is necessary. The facts given, gleaned from the workshops of inventors, are worthy the attention of all. There is

no calling more admirable than that of the inventor. He who does that which has never been done before, and shows his fellow-men how to make improved use of the forces of Nature, confers a blessing on all posterity. The search for that which is not known must ever fascinate the greatest and wisest of men, and the triumphs of investigating genius recorded in this book are but a few of the results of the labor of the thinkers who have kept in advance of the crowd and added to the sum of human knowledge.

The number and value of inventions have increased so rapidly of recent years that the public has come to accept the most marvellous innovations with a readiness that soon makes of them an old story. While there are thousands of people alive to-day who remember the first railroad, the first steamboat, and the first telegraph, we have among us a younger generation who never knew what it was to be without the electric light, the telephone, the electric railway, or the mammoth daily newspaper. The generation that is to come will live in an age of new wonders, and surrounded by new creature conveniences, a few of which we can discern darkly. Some day, mayhap, this book will fall into the hands of some favored one living in an age made vastly more brilliant than our own, and he may smile at the so-called progress here recorded that marks the close of the nineteenth century. Let such an one reflect that there is beyond him a higher and a wider and a greater field of undiscovered knowledge, and that he, too, in his turn, will some day sleep with the useless, lumbering relics of the past.

CHAS. H. COCHRANE.

WEST NEW BRIGHTON, NEW YORK, Sept. 21, 1895.

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THE WONDERS

OF

MODERN MECHANISM.

BIG BUSINESS BUILDINGS.

Towering Steel Structures that dwarf Churches and Monuments —The Principles and Methods involved in their Construction.

MAN is given to admiration for that which is large. The Egyptians who built the pyramids no doubt felt great satisfaction in their achievements, and their work has been admired by all succeeding ages. Within recent years, however, the world has reached a point where business necessities cause the erection of taller and taller edifices, and already the spires of beauteous churches are being dwarfed by apartment houses and office buildings whose owners desire to obtain a larger income from the valuable land which they occupy.

It is not so everywhere. There are great cities, as in Asia and Europe, where one-story and two-story buildings are the rule, and anything above these in height stands out as a landmark. In Havana, Cuba, for instance, they keep to the lower levels, because it is (or was) necessary to "buy the winds"; that is, pay a tax for the privilege of building above a certain height. Thus local laws and

restrictions often make it impracticable to erect tall structures. But in the United States, where large cities spring up in a generation, the increase in land values has been so rapid as to give great stimulus to high building in centres of business. The four-story affairs that were the common thing in the seventies have sunk into the shadow of the seven- and eight-story buildings that are now everywhere to be seen in the most valuable portions of the larger cities of this republic.

While the massive cathedrals of ancient Europe and the more modern Washington Monument prove that it is possible to build to a height of five hundred feet or more with stone and brick, yet the cost of these structures, and the enormous thickness of the walls, make it impossible to attempt such elevations with these materials when building for purely commercial purposes. It is here that modern cheap steel finds an immense and growing market. It permits the construction of tall buildings, with comparatively thin walls and large areas for window spaces, at a cost that is not excessive, and of a strength and durability that are unquestioned. Unfortunately, these steel buildings are not fire-proof, unless the iron is protected against the warping that would result from exposure to great heat followed by the contraction incident to throwing on streams of cold water. It is, therefore, necessary to use a facing of stone, terra-cotta, or the like, giving such buildings the resemblance to the more common stone structures that surround them. Sometimes these exterior stone walls carry their own weight, being simply anchored to the steel frame to insure steadiness, but more often the metal has to carry the added weight of the stone above the sixth or seventh story. For these reasons every added story to a great building increases greatly the total cost of the struc-

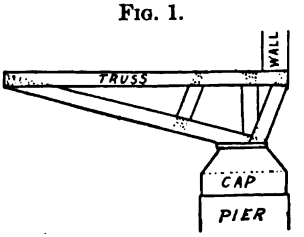
ture, since every story below must be designed to carry its additional weight.

The first consideration of a builder who is called upon to erect one of these towering steel business buildings is the nature of the foundations. If he can build upon the bed-rock, that part of the work is easy, and almost any weight that human beings can pile on will be taken care of by Mother Earth. But frequently he is called upon to build on sand or gravel, or even mud. In such a case he may find almost as much work to do below as above the pavement. In many seaside cities the usual bottom is fine sand or gravel. If this is reasonably hard, and not given to shifting, a pile foundation may be used. The piles are driven in groups all over the building lot, the tops being tied together by beds of concrete, usually fifteen to twenty inches thick, to avoid any chance of spreading, which might otherwise occur where adjacent heavy buildings were removed or excavations made alongside. Such a foundation will bear a weight of forty thousand pounds per pile. If the soil is very soft and yielding, it becomes necessary to resort to other methods. In Chicago, masses of long steel rails have been laid in beds of cement, the rails being so crossed and the whole so connected as to form practically one solid mass, of immense solidity. In a case in New York, caissons, somewhat similar to those commonly used in the construction of bridge foundations, were used with success. The ground was a regular quicksand, and the bed-rock fifty-seven feet below the street-level. To dig down to the rock would have been to undermine surrounding structures. It was therefore decided to sink steel caissons, made like great boxes open at the bottom. The workmen dug inside of these, lowering them as they progressed, and sending up the removed material

through metal shafts that were sunk with the caissons. There were fifteen of these caissons in all, and they were lowered at the rate of four feet a day. When bed-rock was reached the caissons were filled with concrete, brick piers being erected on top, each bearing a huge block of granite for a cap, to support the lower girders of the structure above.

With brick and stone buildings it is customary to rest the walls upon courses of stone, so that the weight is continuously distributed along the line. But with steel structures, involving greater weight with thinner walls, it becomes desirable to distribute the weight on numerous piers. As all such buildings are erected on very valuable ground, it is usually necessary to run the walls to the extreme edge of the property. The walls being but a few feet in thickness the weight would naturally come on the outside of the lot, and the tendency is to tip over the piers upon whose outer edges the walls rest. To avoid this the cantilever truss is commonly used. It is a reversal of the truss used in cantilever bridges, and its construction is best shown by the accompanying drawing. These cantilever girders may be anywhere from ten tons to eighty tons each in weight. The larger sizes are made in sections, owing to the impracticability of handling such heavy masses of metal.

FIG. 1.



The steel and iron used in these structures must be of known good quality, and the specifications customarily require that the maker shall submit to certain tests a piece of each batch rolled, so that the limit of safety may not be

endangered. Good structural steel will have an ultimate strength of sixty thousand pounds per square inch, and wrought iron forty-five thousand or fifty thousand pounds. Where the only strain to be borne is weight, cast iron is nearly as good as steel, and it is often used in the main columns of the lower stories. Both bolts and rivets are used to connect the parts of the steel framing, the latter being considered best. They have to be put in hot, as in bridge-building, and it is an interesting sight to see a riveter catching red-hot rivets in a keg, as tossed to him from an adjacent forge, this method being often used to prevent the bolts from cooling in transit.

Steel columns are commonly made in two-story lengths, the section, or end view, of the metal being in the form of a Z. This shape is nearly as strong as a tube, and presents many advantages that a tube does not. The edges are convenient for the riveting on of braces, tiers, and girders, and the recesses are just the thing for concealing pipes, wires, etc. It is usual to punch all the holes in the steel at the rolling-mill, so that the workmen on the building have only to hoist the pieces in place and rivet them together according to the plans. Great accuracy of work is requisite in order that every part may fit, and every hole come exactly in the right place, for if a hole is made only the thirty-second of an inch to one side it makes great trouble for the riveter. The method of securing uniformity in the position of the holes is to use templates, which are patterns of wood or metal drilled just as the steel is to be punched. By placing this template over a piece, and punching or drilling the holes through the templates, the holes in that piece are made to bear the same relation to each other as the holes in similar pieces.

In calculating the strains on tall buildings wind press-

ure becomes an important item. If it is over two hundred feet high and rather narrow, it is deemed safe to allow for a possible wind pressure of thirty pounds to the foot—a pressure that would blow an empty box-car off a railway track. If there is a tower or finial running still higher, an allowance of fifty pounds per square foot is proper. To meet this pressure angle-braces are put in, or extra wide plate-girders are used at different points to stiffen the frame.

The mechanism used to put the steel and masonry in place is collectively called an erecting-plant. It consists of a platform of a size suitable to be elevated within the walls of the building. Here are placed hoisting devices, as sheer-legs, masts, cranes, etc., together with hoisting-engines. The various heavy pieces are hauled to the spot by teams, tied with great cables, and swung up into place. When the framework for two stories has been thus set into place, the erecting-plant itself is hoisted to the new level, set on solid girders, and the work goes on. If it is to be a twenty-story building or thereabouts, a temporary roof is erected at about the tenth story, to protect the workmen below, who can then go on with the plumbing, plastering, etc., without being subject to a drenching from the rain or a crack on the head from falling rivets.

A very important part of the roof construction in such buildings lies in arrangements for the water supply. City mains are designed to supply only about four stories. These big buildings require large tanks, so constructed that they can never annoy the tenants by freezing, or damage the building by flooding. To avoid the first danger they are surrounded by an attic connected with the top of the elevator-shafts, so that the spare heat of the building always collects around the tanks. The dan-

ger of flooding is further avoided by the use of curved connections, and by placing pipes away from the wall wherever possible. For this purpose they are often ornamentally constructed, so as to be rather an improvement to the looks of a hall or toilet-room. If a stoppage occurs in a pipe, it is easily got at and remedied before any damage results.

The heating arrangements require excessive care, for the comfort and safety of all concerned. The most common plan is to use the exhaust steam from the boilers, providing arrangement for the introduction of live steam when necessary. As there is no pressure in the pipes, and as exhaust steam costs nothing, being the waste after use in the engines, such an arrangement is most economical. Steam-engines or some other source of power are always required to run the elevators, without which no one would ever occupy these great towers. There are often as many as six or eight elevators, set in two or more shafts, so that in case of fire there may be various means of exit for the occupants. Although steam is the common source of power, yet most of the elevators are operated by an hydraulic apparatus, where the pressure of stored water serves to keep a reserve of power, always likely to be in demand in elevator service.

It is possible to put up one of these colossal twenty-story buildings within a twelvemonth. When we consider that many of the great cathedrals of Europe required several centuries for their erection, the dome of St. Peter's at Rome being of itself a work of one hundred years, we the better appreciate the wonders of modern building. And what an army of men are employed, and how systematically they work! The lower stories are finished while the upper ones are in course of erection, and often there

are tenants inside doing business while the work goes on. The most tedious delay is that caused by waiting for the

FIG. 2.

THE MANHATTAN LIFE INSURANCE COMPANY BUILDING.

drying of the plaster. The partitions are made of hollow bricks, which are not accurate as to size. The masons, therefore, lay them even on one side, leaving all the irregu-

larities on the other. A very thin coat of plastering does for the true side and is soon dry, but the uneven side may require an inch or an inch and a half of plaster in some parts. This dries but slowly, and often shrinks so unevenly as to require further plastering to render the surface true. But despite all such delays these big structures seldom occupy two years of time in the building. In one case, that of the Reliance building, corner of Washington and State Streets, Chicago, a sixteen-story structure was made to replace an old five-story building, and opportunity afforded the occupant to keep at least one floor for business during the entire progress of the work, yet the whole was run up without special delay.

The enormous amount of plumbing in one of these great buildings may be inferred from the statement that there are ten and a half miles of water-, gas-, waste-, and vent-pipes in the Manhattan Life Insurance Company's building, corner Broadway and New Streets, New York. Here are also laid thirty-five miles of electric wires. Among other curiosities of construction in such buildings are the great number of steam-pumps. In one case the contract called for twenty-three of these, though the building was designed for ordinary uses. Another novelty is an ice-water plant, which has been introduced with success, being supplied from a refrigerating apparatus in the sub-cellar. The object of this is to avoid the nuisance of having ice carried all through the building by tenants. Fountains are therefore supplied in each of the halls, connected with a special shaft run through the building to carry the cold-water pipes, and keep them separated from steam-pipes and radiators. The method used is to compress air, which in compressing gathers heat enormously. This compressed air is then cooled to a normal temperature by the waste

water, after which it is introduced into a coil of pipe within a water tank. Here it is allowed to expand, and, according to the laws of gases, loses in temperature as much as it gained by compression. This fall in temperature is communicated to the water, reducing it to about 35° or 40° Fahrenheit. It is then pumped up through insulated pipes to the floors above. The waste water returned (after having served to cool the compressed air, as before mentioned, and thereby acquire heat) is used as feed-water to the boilers, effecting an all-around economy.

The cost of these big structures depends more nearly upon the number of cubic feet they contain than would be supposed at first. The extremes are twenty-five and sixty cents per foot, as shown by the following data concerning large buildings of different cities: The Masonic Temple, Chicago, twenty stories, fourteen passenger elevators, rich marble work, cost fifty-eight cents per cubic foot; Pulitzer building, New York, stone front, fire-proof, thirty-eight cents per cubic foot; New England Mutual Life Insurance Company's building, Boston, granite, richly decorated, sixty cents per cubic foot; Monadnock building, Chicago, sixteen stories, rich marble work, forty-two and a half cents per cubic foot; eight to sixteen story office buildings in New York, thirty to sixty cents per cubic foot; Wainwright building, St. Louis, ten stories, twenty-five cents per cubic foot; Union Trust building, St. Louis, fourteen stories, twenty-eight cents per cubic foot; Equitable Life Insurance Company's building, Denver, nine stories, marble wainscoting in first story, forty-two cents per cubic foot; Rookery building, Chicago, eleven stories, ten passenger elevators, thirty-two cents per cubic foot; Brown's Palace Hotel, Denver, nine stories, iron and onyx, thirty cents per cubic foot.

To give the reader an idea of the amount of steel used in one of these structures, it may be stated as a rough estimate that a one-million-dollar steel building will contain perhaps eight million pounds of steel.

A recent improvement in the laying of mosaic floors in these buildings is the use of semi-soft asphalt. By this means the floor is rendered additionally fire-proof, and the asphalt accommodates itself to all shrinkages, so that no cracking results. The mosaics can be made only one inch in thickness, whereas a thickness of from two and a half to three inches is required with a concrete basis.

Steel construction has advanced so rapidly that it is now cheaper for moderately large buildings than either brick or stone. At least one church is in course of erection having a steel framework. This is the Church of St. Mary the Virgin, on West Forty-sixth Street, New York. It is of moderate size, seating a little over eight hundred, and being but one hundred and fifteen feet high, with a ground plan of a hundred and eighty by forty-six feet. About four hundred tons of steel are used in its construction, the frame being entirely of rolled steel. All the visible walls will be of Indiana buff limestone, the composite arrangement being cheaper than if built in the old way, of brick and stone. Steel roof-trusses have been used in churches for many years, but this is the first instance of the durable metal being used for the entire framework. It is an open question whether the cheapness of steel will not eventually result in making it the principal constituent of all buildings of a permanent character. Its durability considered, it is the lowest-priced building-material in the market. The chapter on steel-making will give the reader a better conception of the reasons why steel can now be manufactured at so low a price.

Some details of the great buildings of several American cities may be of interest here. The Manhattan Life Insurance Company's building on Broadway, New York, is twenty-three stories high, and two hundred and forty-two feet from the sidewalk to the top of the main roof, one hundred and eight feet more to the foot of the flagstaff, and four hundred and seven feet from the bottom of the foundations to the foot of the flagstaff. It cost nearly two million dollars, and is believed to be the tallest building ever erected for business purposes.

The American Tract Society's building, corner Nassau and Spruce Streets, New York, is also twenty-three stories high, and the main roof is two hundred and forty feet above the street. With its finial, the total height is about three hundred feet. The contract price for erection was nine hundred thousand dollars.

The Pulitzer building, the home of the New York *World*, on Nassau Street, was at the time of its erection (1890) the tallest business building in New York. It is fifteen stories high, and three hundred and nine feet from the lantern to the ground. Measured from the tip of the flag-staff to the bottom of the foundations, it is three hundred and seventy-five and a half feet. The cost is believed to be about one million five hundred thousand dollars, and the weight sixty-eight million tons.

The Commercial buildings, Broadway, New York, are twelve stories high, arranged in the form of a two-hundred foot cube, and cost one million six hundred and forty thousand dollars to erect.

The City Hall at Philadelphia is believed to be the largest building of any kind in the Western Hemisphere, covering an area of four and a half acres exclusive of the large court-yard in the centre. The central tower is five

hundred and ten feet high, being tipped with a statue of William Penn that increases the height to five hundred and forty-seven feet. This structure is not, however, of the class described, being properly a stone building, though steel is used in the tower.

The Broad Street Station of the Pennsylvania Railroad is the tallest business building in Philadelphia, rising to a height of two hundred and forty feet at one corner. The building proper is ten stories in height, and has a frontage of three hundred and seven feet.

The Betz office building on Broad Street, Philadelphia, is of thirteen stories, and one hundred and ninety-four feet above the sidewalk.

The Masonic Temple, corner of State and Randolph Streets, Chicago, has twenty stories, and rises two hundred and seventy-four feet from the street level. It has fourteen elevators.

The Reliance building, corner of Washington and State Streets, Chicago, has sixteen stories, and is a trifle over two hundred feet in height.

The Ames building in Boston measures one hundred and eighty-six feet from the sidewalk to the top of the cornice, and has thirteen stories. It is the tallest of its kind in New England, and cost about nine hundred thousand dollars.

It is difficult to form an opinion as to how much higher the big buildings of the future may rise, but it may be safely estimated that thirty- or even forty-story buildings are to be expected within a score of years, and that it is mechanically possible to erect steel buildings a fifth of a mile in height, the only serious objection being the cost. These advances would be no more surprising for the close of the twentieth century than the fact that fifteen buildings,

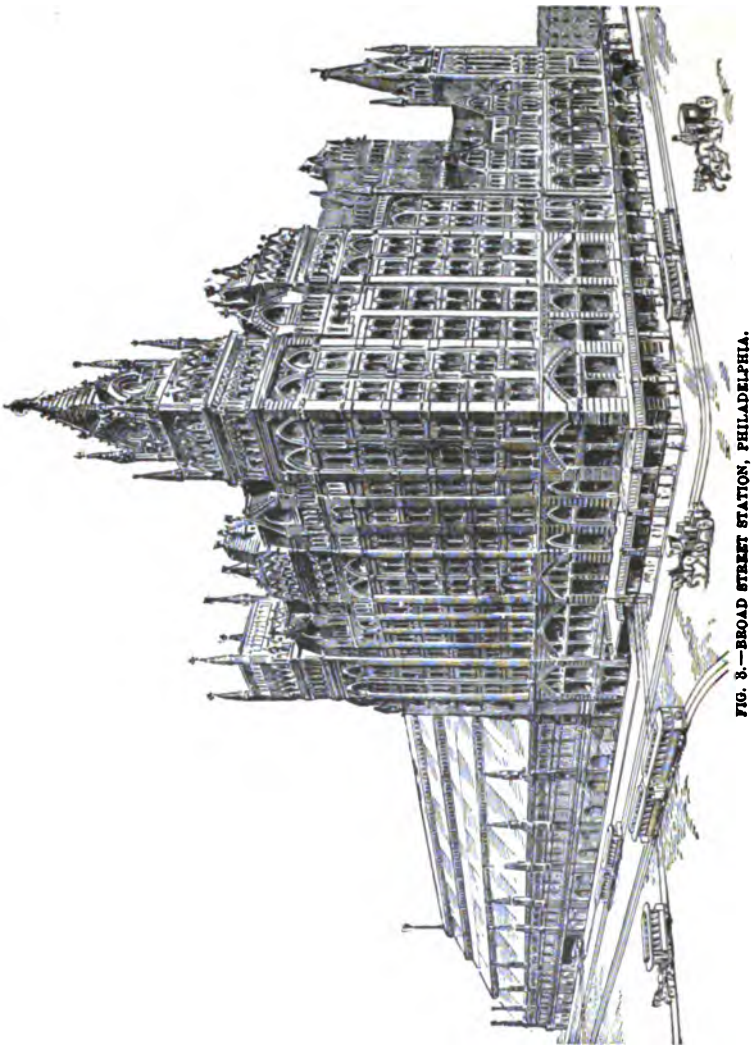


FIG. 8.—BROAD STREET STATION, PHILADELPHIA.

ranging between ten and twenty-three stories, were begun in New York City during the year 1894, a year of general financial depression.

Some reference to the dimensions of the Eiffel Tower seems appropriate here for purposes of comparison, since it was the first large iron structure ever attempted, and opened the eyes of architects and builders to what was possible where steel or iron is substituted for stone. The tower consists, essentially, of a pyramid composed of four great columns, independent of each other, and connected together only by belts of girders at the different stories until the columns unite towards the top of the tower, where they are connected by bracing. There are four independent foundations, each standing at one angle of a square, about three hundred feet apart measuring from centre to centre. The piers are built upon beds of concrete seven feet in thickness, two of them being sunk by caissons much lower than the others, because of the soft soil encountered. Each pier was built with one face vertical towards the centre of the tower, the outer corresponding face being inclined at the same angle as the column of the tower. The other two faces are vertical and parallel. The load carried by the piers is about three tons to the square foot. From the top of the lightning conductor to the ground-level is one thousand feet, but the tower proper terminates at a height of eight hundred and ninety-six feet, with a platform about fifty-three feet square. The width of the column at this level is thirty-three feet, the gallery being carried by brackets. Above the platform rises the campanile. Four latticed arched girders rise diagonally from each corner of the lower part of the campanile and unite fifty-four feet above the platform. By means of a spiral staircase, often in the clouds, another gallery is reached, this one being

only nineteen feet in diameter, and surrounding the lantern which crowns the edifice, at the height of nine hundred and eighty-four feet. Yet above his rises the lightning conductor. Elevators of various kinds run to the different levels. The complete success of the structure has given it a fame equalling that of any of the so-called seven wonders of the world.

The query naturally arises, in closing, What will our big cities be like in another century, if men insist on crowding them full of steel towers? It is hard to predict the result, but it looks very much as though the denizens of small buildings, of say ten stories and under, would have to be satisfied with artificial light and mechanically induced breezes, for Nature's supply of both will be shut out.

EXTRAORDINARY BRIDGES.

A Comparison of the Hanging Highways of the World, with Dimensions of Important Structures.

BEFORE the introduction of structural iron and steel, really great bridges were impossible, as spans were limited to the capacity of stone arches, which have to be constructed on wooden centring that is removed after the keystone is in place. So far as known, the first arched stone bridge of any size was built at Stratford, on the Lea, about the year 1118. It was a toll-bridge, and this singular entry was found among the list of charges: "For every cart carrying a dead Jew, eight pence."

The first iron bridge attempted was at Lyons, France, in 1755. It was to have been an arch, but the work was abandoned, after a portion of the iron had been made, be-

cause of the great expense. In 1777–79 the first iron bridge was built in England, over the Severn River, in Shropshire, the place taking the name Ironbridge. It stands to-day a monument to the durability of cast iron. Its design is that of an arch, of one hundred feet span and forty-five feet rise. The next iron bridge built was also in England, at Wearmouth, in Devonshire. This was no mean structure, being in the form of a segmental arch of two hundred and thirty-six feet span, and costing about twenty-seven thousand pounds. Not until 1803 was the first iron bridge actually erected in France, being thrown across the Seine at Paris. It has nine arches, and a total length of five hundred and sixteen feet. Other cast-iron bridges followed rapidly, until the improved methods of making wrought iron caused it to be substituted. Within recent years wrought iron is giving place to mild steel, which is as cheap and considerably stronger for the same weight.

The first suspension bridge built was over Menai Straits, in North Wales, in 1820–26, at a cost of twenty thousand pounds. The suspension was accomplished by means of sixteen great chains. The length of the bridge over all is a third of a mile, the suspended portion being five hundred and seventy-nine feet in length. The success of this caused another suspension bridge to be built at Vienna across the Danube two years later. The suspended portion of this was three hundred and thirty-four feet, and linked steel bars were used instead of chains. Shortly afterwards a bridge of wire chains, eight hundred and seventy feet long, was built at Fribourg, Switzerland.

The famous Britannia Tubular Bridge across Menai Straits was built in 1846–50, and is so named because constructed of two independent continuous tubes or beams.

Each of the tubes is fifteen hundred and eleven feet long and thirty feet in diameter. They rest on three piers and two abutments. The structure is satisfactory, but as its weight is three times that of a girder bridge of the same strength, it is never likely to be imitated.

M. Gustav Eiffel, the same who built the famous tower, designed a bridge or viaduct that crosses the Truyere Valley at Garabit, and presents some remarkable features of construction. It is fifteen hundred feet long, four hundred feet high, and its centre rests on a metallic arch of five hundred and forty-one feet span. It is built of latticed girders, after the fashion of the Eiffel Tower.

The monarch among bridges is the gigantic cantilever over the Frith of Forth in Scotland. Its magnitude is best illustrated by comparison with other large bridges, as in the accompanying drawing, where it is shown grouped with three remarkable American bridges. How it dwarfs them! Yet the smallest of the four cost six million five hundred and thirty-six thousand seven hundred and thirty dollars, and was seven years in building. It spans the river at St. Louis in three grand arches, each of over five hundred feet. Fourteen men died from the effects of working in the compressed air essential to the sinking of the caissons for its piers, which had to be carried down one hundred and ten feet below the water. This work is not now so dangerous, owing to improved methods. The Poughkeepsie bridge, which ranks next in the group, cost less than three million dollars—an astonishingly economical figure, when we consider that it has five spans of over five hundred feet each, besides shorter spans on each shore of approach, and rises to allow a vessel-clearance of one hundred and seventy feet, in which respect it excels the Forth bridge. The second in the group is the New York-

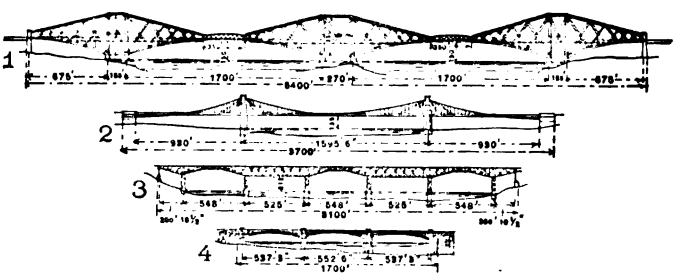
Brooklyn bridge, the proudest structure of its kind on the Western Hemisphere. It cost about six million dollars, exclusive of land damages. Its central span is 1595 feet long, the towers are about two hundred feet total height, and the anchorages contain fifty-six thousand cubic yards of masonry. It is crossed by more people daily than any other bridge in the world.

COMPARISON OF FOUR FAMOUS BRIDGES.

Site	Forth.	Brooklyn.	Poughkeepsie.	St. Louis.
Type of Construction	Steel cantilevers.	Partially stiffened suspension wire cables.	Alternate cantilever and trusses of steel.	Steel arches.
Length of bridge in each case without the approaches, but including the anchorage or abutment	5400 feet.	3700 feet.	3100 feet.	1700 feet.
Longest span of each bridge, centre to centre of bearing	1710 feet.	1596 feet.	530 feet.	520 feet.
Number of railroad tracks that can be used for trains	2	2	2	2
Capacity, expressed in number of freight trains, each five hundred feet long and weighing eight hundred tons, which each longest span may carry with the same coefficient of safety	4¼	1⅓	2	2
Capacity, expressed in number of passenger trains, each five hundred feet long, weighing five hundred and fifty tons fully loaded, which each longest span may carry in ordinary operation	6	2	2	2
Average weight of superstructure per lineal foot of span	19,200 lbs.	7400 lbs.	8200 lbs.	8600 lbs.
Average weight of steel and iron of superstructure per lineal foot of span, without rails, railings, and floorings	18,400 lbs.	6200 lbs.	7300 lbs.	7000 lbs.
Average weight of steel and iron of superstructure per lineal foot of track without rails, railings, and floorings	9200 lbs.	3100 lbs.	3650 lbs.	3500 lbs.
Total cost of construction without approaches, without right of way, and without interest account	$13,000,000	$5,600,000	$2,600,000	$5,300,000
Cost per lineal foot of bridge	2,407	1,610	840	3,150
Cost per lineal foot of track	1,203	805	420	1,575

By the table it will be seen that the great Forth bridge exceeds the others even more in its carrying capacity than in its size. Its piers are sunk ninety feet below high water, and the caisson work on them was done under an air pressure of from ten to thirty-five pounds. The two main spans are each seventeen hundred and ten feet (or about one-third of a mile) long, and the shore spans are six hundred and seventy-five feet each. The main towers are three hundred and sixty feet above the level of high water. This gives an extreme height from the river bed-rock to the top of towers of four hundred and fifty feet. The total length with approaches is nearly two miles. It is justly considered the greatest engineering structure in the world. One of its enormous spans weighs seventeen thousand nine hundred tons, or the equivalent of twenty-five heavily-loaded freight trains. If clumsily designed, it would sink of its own weight. The main compression

FIG. 4.



members of the cantilevers (as the vast balanced frames are called) are tubes of twelve feet diameter and one and a quarter to one and seven-eighths inches thick, this form giving the most strength with the least weight. Each of these tubes is subject to a strain of two thousand five hundred and fifty-five tons of dead load, eleven hundred

and forty-five tons live or moving load, and three thousand two hundred and seventy tons of wind pressure. The plates of which all the cylindrical columns are made are bent into shape while hot between powerful rolls, an extra pressure being applied in a final roll when nearly cold to prevent them from twisting. The site of the bridge is the scene of frequent storms, for which reason an allowance of fifty-six pounds per square foot of strength was made for wind pressure.

The suspension bridge below Niagara Falls has been widely described and illustrated. It was built in 1852, but so many great bridges have been built since then that its length of eight hundred and twenty-one feet now seems little. It is two hundred and forty-five feet above the water.

The vibration on wire-rope suspension bridges is very great, and was not at first fully appreciated by engineers. The first train (and the last also) that was run over the three-hundred-foot bridge at Stockton, California, at the usual train speed of thirty miles an hour, was checked by a wave of vibrations that rose before the locomotive to a height of two feet. After that the train speed on the bridge was limited to three miles an hour.

Among interesting foreign bridges the following may be named: The bridge over the Hooghly River at Calcutta, built of iron girders, and resting on twenty-eight pontoons. It is elevated to allow the passage of small river craft, and is fifteen hundred and thirty feet long and sixty-three feet wide. The Chilean State Railway bridge, over the Mallen River, which it crosses at a height of three hundred and thirty-three feet. It is fourteen hundred and nineteen feet in length, and includes five spans. The movable ferry bridge at Bilboa, Spain. This is simply

a high iron-girder bridge, which, instead of having a roadway, bears a large basket-like platform, or car, swung underneath so that it may be run across by a travelling crane, carrying over a load of passengers and freight. It is built high to admit of the passing of vessels, and it has the advantage that no shore approaches are required, thus lessening the cost materially. The span is about five hundred feet, and one hundred and fifty passengers may be carried across at a time, the trip occupying only one minute.

A bridge is planned to cross the Hudson at New York City with a single span, connecting the States of New York and New Jersey. It is to cost twenty-five million dollars, and will be the largest as well as the most costly bridge on the globe. There appears to be no doubt that it will be begun at an early date. The great bridge will be of the suspension type, the clear span being one hundred and fifty feet in height and three thousand one hundred and ten feet (nearly two-thirds of a mile) in length. This is almost double the span of the famous Forth bridge. On the New York side will be approaches of five hundred and seventy-five feet span and four hundred feet span respectively. On the New Jersey side the approaches are made up of short deck spans. The two main towers will be five hundred and eighty-seven feet above high water, or about seven hundred feet from the bottom of the foundations. These towers will have eight legs, braced in two directions, and resting upon masonry piers set on the bed-rock. The main steel cables, twelve in number, will be twenty-three inches in diameter, and will bear a tensile strain of one hundred and eighty thousand pounds per square inch. Six tracks will cross the bridge on a level, and each track is designed to bear three thousand pounds

load per lineal foot. The load upon these tracks will be distributed by the use of stiffening trusses every one hundred and twenty-five feet. The trusses will be of bow-string design, and will be constructed of high-grade medium steel. A system of lateral bracing is provided at the floor level to resist wind pressure. There is also a vertical set of vibration braces at each panel point, connected with top chord lateral bracing. The ends of the cables will be set into anchorages of masonry made by running long tunnels under ground.

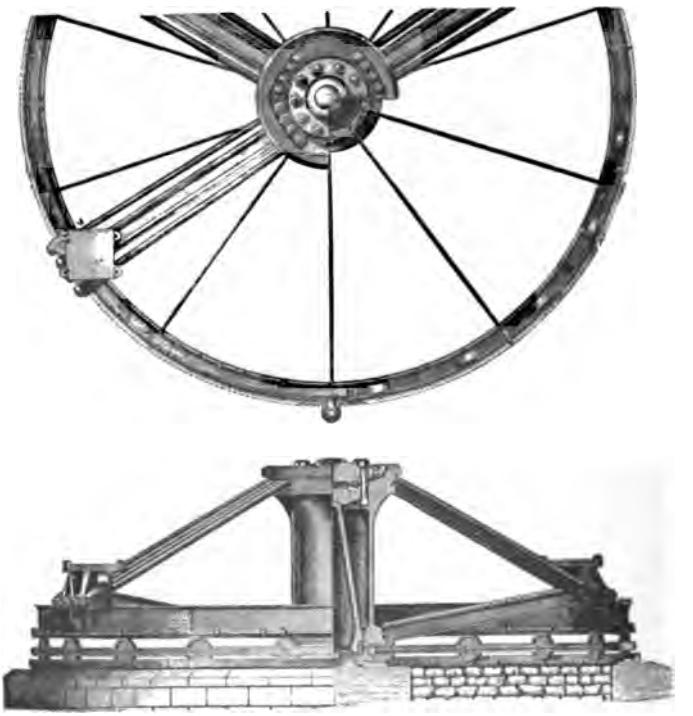
Among drawbridges the swinging form has become the more popular type. They might better be called rotating than swing bridges, because they have a purely rotary motion. The mechanism of the pivot-centre of a substantial type, as made by William Sellers & Co., is shown herewith. The weight is designed to be carried upon the plates of the centre-post, the rollers of the circular track simply serving to prevent tipping.

The longest bridge in the United States spans the Ohio River at Cairo, Illinois. It is ten thousand five hundred and sixty feet, most of which is taken up in the approaches. It has seven principal spans and forty-three minor ones. Over twenty-one million pounds of steel enter into its construction, besides thirty-two thousand yards of masonry. Another bridge over the Ohio River at Cincinnati is a trifle over six thousand feet long, and is principally remarkable for the very large steel girders used in its construction, many of them weighing thirty-seven thousand tons each. The largest cantilevers used in a bridge in this country are across the Colorado River just below the Needles, where there is a span of nine hundred and ninety feet. The Memphis (Tennessee) bridge over the Mississippi is a notable structure. The longest of

its three main spans is seven hundred and twenty feet. It is built on the cantilever principle and rests on four piers.

Iron bridges are commonly made of trusses, which bear various names. Among the most common is the Howe

FIG. 5.

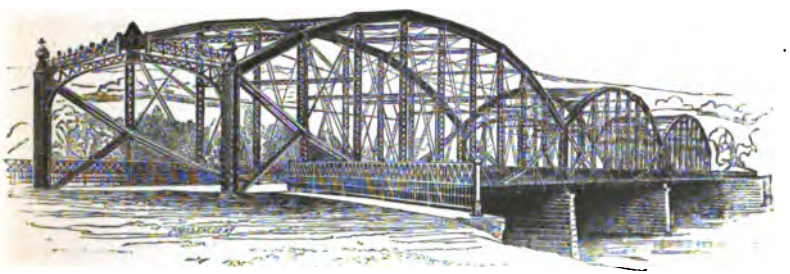


PIVOT-CENTRE FOR SWING-BRIDGE.

truss, consisting of X-shaped braces between beams or girders. The triangular or V-shaped truss is also common. The parabolic truss is a comparatively new and handsome form, and is shown in Figure 6. The lattice form of girder is also a favorite style of construction.

It has an upper and a lower beam connected by a lattice-work of crossed bars. The plate bridge or plate-girder bridge is made of very wide steel beams, usually in cross section resembling an I. Such bridges are called deck bridges when the roadway is on a level with the top of the trusses, through bridges when the roadway passes between the trusses on a line with the lower beams, and half-deck when the roadway is midway of the trusses.

FIG. 6.



HIGHWAY BRIDGE AT BINGHAMTON, NEW YORK.

Bridge-building is undoubtedly on the increase, and with the decreased price of steel, together with the increased strains which it is made to bear, we may reasonably expect to see many more such mammoth structures as that contemplated over the Hudson. Indeed, greater ones are possible with present materials, and the cost is the only thing that prevents the building of spans a mile in length. As materials cheapen, and the world's ideas of necessity and convenience advance, probably the one-mile span will spring into being.

SOME GREAT TUNNELS.

Methods of blasting through Mountains, driving Shields under Rivers, and forcing Needles under City Streets.

NEXT to the aspiration for fame that leads men to erect sky-kissing towers, there comes the desire to dig far down into the bowels of the earth, to scorn the opposing mountain that will not be crossed, and make a straight road through its vitals to daylight. No engineering feats are more interesting and none have called for grander genius than the construction of great tunnels. According to an estimate of 1894, there are in the world about eleven hundred and forty-two tunnels worthy of the name. One thousand of these have been built for railway purposes, and their total length is three hundred and fifty miles. Twelve are subaqueous, affording passage under rivers, and of a total length of nine miles. Ninety have been built to allow the passage of canals, and their length is seventy miles. Forty have been made as conduits for various commercial purposes, and their length is eighty-five miles, the total length being five hundred and fourteen miles, or about half a mile each. These figures seem disappointingly small at first sight, but the work in special cases has proved sufficiently difficult to satisfy the most exacting seeker after onerous and arduous engineering enterprises.

When ancient Babylon was in her prime, a tunnel of masonry was constructed at that point under the mighty Euphrates. The Romans also built many tunnels, the most important of which was the one constructed to drain Lake Fucinus, which was built shortly after the time of Christ. It was three and a half miles long, and had twenty-two perpendicular shafts, some of them four hun-

dred feet long, serving to carry away the waste dirt and to convey supplies to the workers. Copper hoisting-buckets were used in these shafts and operated by windlasses from above. The enormous number of thirty thousand men are said to have been employed in the tedious task of digging it by hand labor.

There are four mountain tunnels that are regarded as among modern wonders of engineering. They are the Hoosac, Mount Cenis, St. Gothard, and Arlberg. The Hoosac is almost five miles in length, and occupied twenty years in the building, at a cost of about sixteen million dollars. The Mount Cenis, seven and five-eighths miles long, occupied fourteen years, at a cost of fifteen million dollars. The St. Gothard, the greatest of all, nine and a half miles in length, was finished in nine years, at a cost of eleven million one hundred and seventy-five thousand dollars. The Arlberg, six and three-eighths miles long, occupied three and a half years in construction, and the cost was seven million three hundred thousand dollars. They are given in the order of their construction, the Hoosac being begun in 1855, Mount Cenis in 1857, St. Gothard in 1872, and Arlberg in 1880.

It will be observed that the time and cost per mile were reduced in each succeeding work. A large portion of the work on the first two was done by hand, with very inefficient machinery. The Hoosac was in many respects the most difficult feat of the four, since it was the first of its kind, and involved many problems previously untried, and it is gratifying to think that if European engineers have surpassed Americans in the size and number of their great tunnels, at least our engineers showed them the way, and made success easier in later examples.

The Hoosac passes under two mountains, one fourteen

hundred feet and the other seventeen hundred feet higher than the level of the tunnel. Between them is a valley or gorge whose bottom lies within a thousand feet of the tunnel roof. In this gorge the work was begun, and a shaft sunk to the grade of the tunnel, which here reaches its highest point. From the shaft tunnelling was begun both ways, which, with the headings sunk at the extremities of the route, enabled the work to progress in four directions. It was remarked of the Mount Cenis tunnel that the engineers must have been very sure of their measurements, since they worked from both ends. Our engineers set themselves a doubly difficult task of the same sort, and their four roads met in the bowels of the mountains with an error of only two or three inches. The last ten years of their work were considerably lightened by the introduction of the compressed-air rock-drill, which came into use about 1865 for drilling blasting-holes.

The most important of the railway tunnels made in the United States within recent years is the Stampede or Cascade tunnel, on the line of the Northern Pacific Railway. This tunnel is over two thousand eight hundred feet above the sea level, and is nine thousand eight hundred and fifty feet long. The difficulties of its construction were increased by the fact that the work had to be done in a wild unsettled region, and that the contractor was allowed only twenty-eight months in which to complete the undertaking. It was finished in 1889, exactly on time. A description of the methods of work will serve to show how all such tunnels are now constructed. The points of entrance to the mountain having been decided upon, they were accurately located as to line by taking a sight survey across the top of the mountain. This was done with a transit so accurately that the headings met within an inch of the

calculated points. The contractors then built a railroad across the mountains for their own use, at a cost of four hundred thousand dollars. Curiously enough, they sold it afterwards at a good profit. After some six months spent in building this road and getting the tools and machinery on the ground the real work was begun. The headings were run in two levels or steps, the upper level being kept about thirty feet in advance of the lower level. This allowed the using of about twice as many men and machines for drilling as could have been accommodated if the work had been all done on one level. It permitted the men working on the upper level to bore downward, as well as into the face of the rock, more than doubling the area of rock available for drilling. The blasting-holes were drilled about five feet apart and twelve feet deep. In soft rock each drill was expected to bore six or seven of these holes in five hours, when all hands retired to get out of the way of the blast. Four hundred pounds of powder were used for such a blast. Of course if the rock was specially hard the work progressed more slowly, and sometimes only five or six feet of advance were made to a blast, after fifteen hours of hard drilling. By using two shifts of men, work was kept up night and day, and an average advance of nearly seven feet a day was obtained in each heading. About three hundred and fifty men were on the pay-rolls during the whole period, and thirteen of them were killed by accidents, which was considered to be below the average record.

The work of timbering progressed with the drilling and blasting, and interfered with the drillers about one-fourth of the time. The tracks were laid close after the workmen, so as to run cars back and forth for removing the débris. A novel arrangement, designed especially for

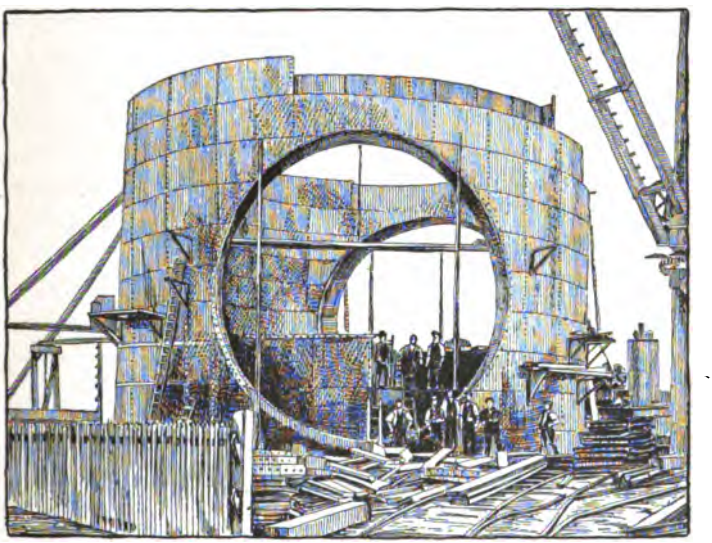
this work, was in the use of a sort of two-story flat-car, built to run entirely above and around the ordinary dump-cars, so that when they met in the tunnel the dump-cars passed underneath the big car which ran on outer tracks. This big, two-story car was the same height as the upper level on which the workmen operated the drills, and was used to carry off the upper rock and earth after blasting. The contract price for this tunnel was one million one hundred and sixty thousand dollars, but the Northern Pacific Railroad found it necessary later to put in masonry arches and concrete to protect the rock, which was shale, from the damaging moisture of the atmosphere, which work added materially to the cost.

The Croton aqueduct in New York is properly a tunnel, though it does not go by that name. It is thirty miles long, and almost wholly under ground. It is not only the longest but the most costly of modern tunnels, the expense being about twenty-four million dollars.

The tunnelling of rivers to secure a convenient means of crossing without interfering with navigation, suggested itself in ancient times, but the first modern instance was about 1800, when the Thames tunnel was projected. So little interest was taken in this, however, that it fizzled along for over forty years before completion. The greatest subaqueous tunnels have been built by the English, those under the Severn and Mersey being each nearly five miles in length, the former over five miles if the approaches be included. It was built at a cost greatly in excess of the original estimates, the soft soil being subject to a leakage almost impossible to overcome. Twice during tunnelling operations the work was flooded, with loss of life and great damage. Had the difficulties been fully foreseen at the outset it never would have been undertaken, as it

affords only a slight saving in time of travel. But the British spirit is apt to carry things through, and this tunnel stands as an example of man's triumph over the forces of nature.

FIG. 7.



CAISSON IN COURSE OF CONSTRUCTION FOR BLACKWALL TUNNEL, UNDER THAMES.

In subaqueous tunnelling the hydraulic shield is commonly used. This is the invention of Alfred E. Beach, of New York. It was used with success on the tunnel under the St. Clair River at Sarnia for the Grand Trunk Railway of Canada. This tunnel is six thousand feet long, two thousand three hundred feet being under the river bottom. It was finished in 1890, and a description of the methods employed will serve to give a fair idea of modern methods of building river tunnels. The soil was principally soft clay, with occasional beds of gravel and

quicksands. This is usual in river beds, and as a consequence the methods of work are entirely different from those employed in tunnelling through rock, as under mountains. A steel cylindrical shield was used, twenty-one and a half feet in diameter and fifteen and a quarter feet long. It was made of one-inch steel plate, and was forced forward a foot and a half at a time by a series of hydraulic jacks pressing against the rear edge. These jacks were capable of exerting a thrust of three thousand tons, hence the shield would push aside any ordinary small boulders that might chance to be in the way. The shield had rear doors, through which the workmen who removed the clay, etc., might escape and shut off the flow if any sudden stream of water should burst in on them. The excavated material was passed back through these doors and run out upon small dump-cars. As the work progressed under the river, bulkheads constituting air-locks were placed back of the workmen and compressed air supplied them, to a pressure sometimes as great as twenty-eight pounds. This served as a check to keep back the water, which otherwise would have flowed in almost constantly. As the shield was pushed forward, cast-iron rings two inches thick were inserted behind it. By making these rings slightly oval instead of circular, a ring can be passed into place through rings of the same size by simply turning it so that its narrowest diameter comes opposite the widest diameter of the rings already in place and forming the tunnel. In this tunnel, however, it was deemed best to make the rings in segments and bolt them together. The shield was made with a rear hood an inch larger in diameter than the rings, and the latter were readily put in place within the protection of this hood. If the shield showed a disposition to work to one side, the jacks on that side were subjected to

a trifle more pressure, and thus the work was kept practically in line, so that the shields from the opposite sides of the river met accurately in the centre as calculated. The six thousand feet of shield work were completed in just one year, and at no time was there serious annoyance from water. Practically the same method has been used in tunnelling under the streets of cities, where it was important not to interfere with buildings above. The Croton aqueduct under Broadway, New York, is built in this manner, as is also the London Electric Underground Railway tunnel.

At King's Cross Station in London an ingenious system of tunnelling was successfully used. It is useful in a clay soil, and consists in driving sheet-iron piles, or needles, through the clay horizontally, so as to support the clay above when material is removed from below. These needles are ten and a half feet long and a foot wide, and are tongued and groved like matched boards, so that nothing can work through between them. They are pushed forward as the work advances, and the space of two inches which they leave vacant is filled with cement, forced in through pipes under pressure. In this way foundations above are not interfered with in the least. This is cheaper than shield-work, and quite as suitable for tunnelling under cities.

For tunnelling in chalk there is probably no better method than that tried in the proposed tunnel under the English Channel, about 1882. The engineers used steel cutters, mounted upon the ends of a rotating arm. This machine cut into the rock at a rate as high as eighty-seven feet in a day of twenty-four hours, a speed never approached in any other tunnelling operations. Unfortunately, political jealousies have prevented the completion

of this work, though about a mile of progress had been made on each end. No doubt the commercial advantages of such a tunnel between France and England will eventually cause the resumption of this interesting tunnel, and make it possible for Londoners and Parisians to travel back and forth without danger of sea-sickness.

CANALS, OLD AND NEW.

A Brief Description of the Great Artificial Waterways of the World, with a Summary of Important Proposed Additions.

THE earliest record we have of a canal enterprise dates back sixteen hundred years before Christ, to the time of Sesostris, when, according to tradition, a canal existed across the Isthmus of Suez, where to-day is located the greatest canal in the world. It is very possible that this is true, since the isthmus is nothing but a sand formation, and may have been very much narrower in those days than at the present time. The great Imperial Canal of China was built many hundreds of years ago, and is still in use. Canal-building is in principle the simplest of engineering enterprises, consisting mainly in digging a path for water. There are other problems that arise in a country where hills and streams abound, but these would not have troubled the ancient Egyptians, since the land is dry and sandy.

Whether this time-honored tradition be true or not, it is well established that both Darius and Nero contemplated cutting the isthmus, and the historian Harcourt, who wrote a book on "Rivers and Canals," states that there is evidence that a canal existed here from 600 B.C. to 800 A.D., when it was allowed to fall into decay, and gradually disappeared.

In more modern times, Pope Sixtus V., Louis XIV., and Napoleon I. each had the building of a canal at the isthmus under advisement, but without ultimate result.

The Dutch, always troubled by an excess of water in Flanders, began to cut canals about the twelfth century, and in 1560 they finished a great canal connecting Brussels with the Scheldt. In France, the first canal enterprise of importance was the Canal du Midi, or Languedoc, which was finished in 1681. This was a really great enterprise, being one hundred and forty miles long, and costing seven million two hundred thousand dollars. It has one hundred and nineteen locks, but is hardly a ship-canal in the modern sense, since it was designed to contain but six and a half feet of water. Great Britain's first canal was built in 1572.

Canal-building may be regarded as the engineering science of the eighteenth century, since it flourished principally between 1725 and the era of railroads, about 1830. At the time that Stephenson ran his first locomotive there were more than six thousand miles of canals in successful operation. Probably one-half of these have gone into disuse, as they were designed to carry freight, which is now more conveniently transported by rail. Modern canals are built usually for the passage of large ships between contiguous bodies of water. Prominent among the canals of the old style is the Erie Canal, three hundred and sixty-three miles long, connecting Lake Erie with the Hudson. It was finished in 1825, at a cost of fifty-one million six hundred thousand dollars. There have been in all about five thousand miles of canals built in the United States, about half of which are now in a state of desuetude. England has four thousand seven hundred miles of canals, much more than any other country in the world.

The great Suez Canal, which made De Lesseps famous, was begun in 1859, and finished within ten years, at a cost of about eighty-three million dollars. It is ninety-five miles long, and was twenty-six feet deep, but since 1866 workmen have been engaged in deepening it, at an estimated cost of forty million dollars more. Its annual tonnage, which in 1870 was four hundred and thirty-six thousand six hundred and nine, has steadily increased, and is now over ten millions. The stock is quoted at about five times the par value.

The unfortunate Panama Canal enterprise, which failed under the leadership of De Lesseps, was to have been forty-seven miles long, and the estimated cost was one hundred and twenty million dollars. It was begun in 1881, and two hundred and fifty million dollars were expended in completing about one-third of the work, when it collapsed, under speculative financiering, amid grave scandals.

It is more interesting to turn to the Isthmus of Corinth Canal, which was opened in 1893, after nine years' labor. It is but four miles long, yet saves two hundred miles of navigation, and is expected to have a traffic almost half as large as the Suez Canal. Nero began a canal at the same place eighteen hundred years ago, and traces of his work are still to be seen in the vicinity. That tyrannical monarch is said to have turned the first sod himself with a golden spade, but after some time abandoned the work because the scientists of that day told him that the sea was higher on one side than on the other. May 2, 1882, the king of Greece started in a silver spade, while the queen did more efficient work in touching off a train of dynamite mines. A firm contracted the job of completing what the king and queen had begun so magnificently for five million two hundred

and eighty thousand dollars, but found more rock than they anticipated, and failed. It was finally completed at a cost of about twelve million dollars. About three thousand men were employed at the period of greatest activity, together with seven hundred cars and eight dredges. The deepest cut is two hundred and twenty-eight feet. There are no locks.

A remarkable canal that is but little known is the St. Mary's, or Sault Ste. Marie Canal, forming the outlet of Lake Superior to Lake Huron. It has the largest lock in the world, being eight hundred feet long, one hundred feet wide, and having a lift of eighteen feet. Its tonnage is double that of the Suez Canal. It is only one mile long, was built in 1855, and has been twice enlarged. Its great lock, only recently completed, is manipulated wholly by hydraulic power taken from the fall at the lock, so that the only expense is for maintenance and attendance. The charge to passing vessels is about one-half cent per ton.

The city of Chicago has dug or is digging a canal to connect the Chicago River with a tributary of the Mississippi, desiring, for sewerage purposes, to divert the Chicago River from Lake Michigan. The work is to be extended ultimately to the Mississippi, at a depth of fourteen feet. It will probably cost some sixty million dollars before completion.

The Manchester Ship-Canal, completed in 1894, is thirty-five miles long, and cost seventy-five million dollars. Manchester is sixty-five feet above the sea-level, and five locks were necessary to elevate the incoming ships. Should this prove profitable, there is no telling how many inland cities will become seaports. This canal is chiefly remarkable for its great width, being one hundred and twenty feet wide at the bottom. Its construction presented some

unusual difficulties. The Mersey River, which is one of the most crooked on the globe, lay so in the way that it had to be crossed six times, while the Bridgewater Canal had to be crossed once. This latter was accomplished in a novel manner. Across the Manchester Canal is constructed what might be called a swinging water-bridge. Into this the Bridgewater boats are hoisted by an hydraulic lift, swung across the Manchester Canal, and let down on the other side by another lift. The swinging water-bridge is then turned to one side, and traffic continues on the Manchester Canal until another Bridgewater craft demands passage.

The Baltic and North Sea Canal is an important engineering work, begun in 1887 and opened in 1895. It cost forty million dollars, and will save vessels the dangerous trip by way of the Cattegat around the north shore of Denmark. Nearly three thousand vessels have been wrecked in passing through this sound within thirty years, with a loss of life of over seven hundred. Prussia's importance as a naval power will be augmented by the canal, which was an equally potent reason with that government for undertaking the work. It is sixty-one miles long, and twenty-nine and a half feet deep, sufficient to carry the largest vessels in the German navy. It is expected to afford accommodation to twenty thousand ships annually. The working plant consisted of ninety locomotives, two thousand four hundred and seventy-three cars, sixty-eight dredges, one hundred and thirty-three lighters, fifty-five steam-engines, and four thousand seven hundred to eight thousand six hundred men. It has tide-locks at either end, the one on the Baltic end being usually left open. A speed of five and three-tenths miles an hour will be allowed passing vessels. The toll will be seventy-five pfennigs (eighteen cents) per ton capacity. It should be

stated, in this connection, that there are already three canals connecting the Baltic and the North Sea, all of them old-time affairs of little depth, and two of them having been abandoned. The present canal is an almost direct cut, and is specially designed to allow of quick travel for the Prussian gunboats. It will be a saving to commercial vessels of three or four hundred miles.

Projected canals are of quite as much interest as those which have existed in the past or are being built in the present. One of the most remarkable is a long-mooted enterprise for connecting the North Sea with the Mediterranean by cutting across France. There are two routes now under consideration,—one via Marseilles, Lyons, and Dunkirk, and the other by Marseilles, Lyons, Paris, and Rouen. That portion of the canal from Rouen to Paris, a distance of over a hundred miles, is most seriously considered.

There is agitation in several English commercial cities for a closer intimacy with old Neptune. A ship-canal to London, at a cost of five million dollars, is mooted. The towns along the Trent want a barge-canal, while those on the Mersey talk of a ship-canal, eleven feet deep, to cost eleven million dollars. Birmingham is very likely to put through a ship-canal to the Severn, at a cost of six or seven million dollars. An extension of this scheme is desired by merchants of the manufacturing centres tributary to the Bristol Channel, the projected route being from Stalford, on the Bristol Channel, via Taunton to Seaton, a distance of sixty-two miles. This would cost about fifteen million dollars more. Other proposed British canals are from the Tyne to the Solway Frith and from the Clyde to the Forth.

A canal route has been surveyed across Italy, from Fano on the Adriatic to near Castro on the Mediterra-

nean. It would be one hundred and eighty miles long, and an undoubted gain to navigation, but the estimated cost of one hundred million dollars stands in the way.

Austria desires a canal, deep enough for war-vessels, cutting from the Danube, near Vienna, to the Oder, near Breslau, thus connecting the Baltic and Black Seas. The distance is two hundred miles, but the route is easy, so that the cost is set down as not over thirty-seven million dollars. Other proposed enterprises in that part of the world are a canal to connect the Black and Caspian Seas, and another to cut the Isthmus of Perekop, which unites the Crimea with the mainland.

It has been proposed to fulfil the prophesy in Ezekiel, and obliterate the historic Jordan, Dead Sea, and Sea of Tiberias, by running a canal from Acre on the Mediterranean to the valley of the Jordan and on to the Dead Sea, which would then be flooded, as it is thirteen hundred feet below the sea-level. This section, sacred to so many Christians, would be turned into a lake of one hundred and forty-seven by ten miles, connected on the north with the Mediterranean by a sixty-seven-mile canal and on the south with the Gulf of Akabah by a two-hundred-and-forty-mile canal. It is claimed that this would make a route to India four hours shorter than the Suez Canal, and that it would cost less than one hundred million dollars to build it. The scheme is generally regarded as a lever for English merchants to use in keeping down tolls on the Suez Canal. Another canal for the same purpose, connecting with the Persian Gulf, has been suggested.

On the Western Hemisphere we have the continually mooted question of a canal dividing North and South America, with De Lesseps's gigantic failure at Panama to check the enthusiasm of investors. Let us hope that the

Nicaraguan plan, with its one hundred and seventy miles of route and estimated cost of seventy-five million dollars, will be put through.

In the United States there has been proposed a ship-canal to connect the Chesapeake and Delaware Bays, by a thirty-mile route, at a cost of ten million dollars. This would bring Baltimore two hundred and eighty-six miles nearer Philadelphia by water, and save coasters two hundred and fifteen miles between Baltimore and New York. A canal around Niagara Falls on the American side is frequently discussed, since the Welland Canal, which forms the connection on the Canadian side, is only fourteen feet deep. The new canal would have to be twenty or twenty-five miles long, and would cost eighteen to twenty million dollars. Of course there have been plenty of people who desired to cut the Florida peninsula. A company was once organized for the purpose, but failed to raise the required forty-six million dollars.

Another project is the enlargement of the Delaware and Raritan Canal for the use of vessels of deep draught. This would complete an inland route via the Cape Cod Canal (now under way), the proposed Delaware and Chesapeake Canal, and the Dismal Swamp Canal, forming a convenient protected waterway between Boston, New York, Philadelphia, Baltimore, Norfolk, and the Carolina Sounds. Such a route might become of vast military importance in case of a war with some foreign naval power, which blocked our ports. Admiral Luce made this project the substance of a government report, showing how it might enable us to gather our navy at any point on the Atlantic coast, possibly without the knowledge of a hostile fleet, and probably without their intervention.

Among other proposed canal enterprises in this country

are the following: From Lake Borgne to the Mississippi; length, twelve miles; cost, four hundred and fifty thousand dollars; would save two hundred and sixty-five miles of gulf navigation. Cincinnati and Lake Erie; enlargement of present canals; cost, twenty-eight million dollars. Fresno and San Joaquin Rivers; cost, three million dollars. Saugatuck to Detroit via Kalamazoo River; length, one hundred and seventy-eight miles; designed to complete an air-line water route between New York and Chicago. Bay Autrain on Lake Superior to Little Bay de Noquet on Lake Michigan; length, thirty-six miles; cost, five million dollars; would save two hundred and seventy-one miles between Duluth and Chicago. Lake Erie to the Ohio River; length, one hundred and thirty-six miles; designed to connect the Great Lakes with the Gulf of Mexico. A ship-canal, through the Great Lakes, wholly in American territory. The Dominion of Canada has a similar one all on British territory, built at a cost of sixty-seven million dollars.

From this it will be gathered that canal-building is not on the decline, but that interior waterways are sufficiently esteemed by civilized nations that they will be built wherever demand arises, if the contour of the ground permits. Their advantage as a means of cheap freight transportation, and for quickly gathering the vessels of a navy, cannot readily be overestimated.

It is very possible that barge-canals may receive a substantial boom because of electrical propulsion, which has been tried successfully of late. If trolley railways can carry passengers cheaper than steam-railroads, why cannot trolley canals carry freight cheaper than the steam-railroads? This is the question which those who are studying the matter are trying to solve. During the latter part of

1893, F. W. Hawley, of Pittsford, New York, began experimenting with street-railway motors mounted on a canal-boat and operating a propeller-screw placed at the rear, the power being derived from double overhead trolley wires. A fairly satisfactory result was obtained, and a plan

FIG. 8.

THE TROLLEY TUG ON THE CANAL DE BOURGOGNE.

was then devised for allowing such boats to pass each other on the canal. This is accomplished by supporting the trolley-wires on cross-wires so that the trolley wires are free to slide sideways on the insulating connections. As it would be expensive to fit up all canal-boats with motors, it has been proposed to use propeller tugs, or to make a detachable stern-post, bearing the rudder and motor. The principal objection, however, to the whole project is that urged against all methods of power as applied to canal-boats—the banks would suffer from wash, and it would cost more to keep them in repair than would be saved by improved methods of propulsion. If we are to have trolleys and screw-propelled boats on canals we shall have to rebuild them with permanent masonry banks that are not affected by wash. We might then run the canal-boats at twenty miles an hour, if that proved to be an economical

speed. If rebuilding is considered an unremunerative investment, we can at least adopt the German method of drawing the canal-boats by means of a tug that picks up a chain from the bottom and runs it over a reel, drawing itself along. The Germans use steam-power on the tug, but if we made use of a motor, driven by the overhead trolley, it would appear to be a saving, and there would be no wash of the banks, as where a propeller is used. This has actually been done on the Canal de Bourgogne in France. A portion of the canal, about three miles and three-quarters long, is in a deep cutting and tunnel, where a tow-path was impracticable. A submerged chain and steam-tug were therefore provided for propelling the barges through the cutting. As there was ample water-power in the vicinity, it was decided later to abandon the tug, and in 1893 a power-house was built, with a trolley-wire over the canal. An electric tug takes the current by means of a trolley-pole, and the work of towing the barges is all done by a neighboring waterfall of twenty-three feet. The submerged chain is picked up and passed around a drum on the tug, and by hauling on this the tug makes slow headway with its tow. The tug motor is nineteen horse-power. The cost of canalage through the tunnel by this method has been reduced from a slight fraction over two cents a ton by steam-power to one and four-tenths cents per ton by trolley, and the time of passage is slightly shortened. The cost of installing the electric plant was twenty-seven thousand dollars.

It is only a question of time when some such improved methods of propulsion come into use on all canals, or else the canal-barge must become a thing of the past. It is already behind this progressive age, and requires to catch up to avoid being dropped.

ELECTRICITY AND ITS FUTURE.

The Nature of the Electric Fluid, and the Wondrous Possibilities that lie before Electrical Inventors.

ELECTRICITY is the modern agency by which we may produce action at a distance. It has been compared to an infinitely flexible connecting-rod, by means of which we can transmit energy and reproduce it in any desired form at a distance. By its aid we can turn the sunshine of thousands of years gone by, whose energy is stored up in coal—we can convert this sunshine back into light, or heat, or, better still, we can reconvert it into energy and make it do our work.

FIG. 9.

There is a good deal of unnecessary mystery about this wonderful force which man has so lately harnessed and brought under control. Either scientists and electricians are too prone to keep their knowledge of what it is to themselves, or else there exists among them a great lack of ability to express in plain understandable English just what electricity is. Some of them go so far as to say that we do not know what electricity is, that we can judge of it only by its effects, and that we have learned, partly by accident and partly by experiment, that it is governed by certain natural laws, and that under given conditions it will do certain things. While all these statements are true, they are only half-truths. That is the way to tell a thing when you wish to overshadow a man with your learning and keep him from getting at the truth. Is it not true of all the forces of Nature that we judge of them by their effects? There is a philosophic theory that man

cannot really know anything, but simply receives impressions of what exists about him. That is one way of putting it, but some impressions are much more vivid than others. A blow on the head with a club is the policeman's method of conveying the impression to a ruffian that he must behave himself and cease to make trouble. That sort of impression is easily conveyed. But the impression as to what electricity really is has not entered clearly into the mind of one educated person in a dozen. Even this sweeping assertion probably understates the fact. Let us take a definition from one of the authorities. This will serve as a fair average statement of the case: Electricity is "an imponderable and invisible agent producing various manifestations of energy, and generally rendered active by some molecular disturbances, such as friction, rupture, or chemical action. At rest it is called static, is produced usually by friction, manifests itself chiefly in attractions and repulsions and violent discharges like that of lightning, and has no use in the arts. In motion it is called dynamic or current electricity, and this form has been widely developed."

This is as scholarly and concise a statement as can be found in any text-book. But the man who is trying to learn what electricity is turns from it with a sigh—it has not conveyed the idea to his mind.

Let us try and see if we cannot make this thing clear. The primary reason why we do not comprehend electricity readily is because it does not easily or directly manifest itself to our senses. True, we see it in the electric arc, we feel it in the battery, and we hear it in the thunder's roar; but we know that the electric fluid is all about us, in us, and through us when we experience no sensations of its presence. We therefore fail to comprehend it, just as

a man born blind fails to comprehend light, or a deaf mute to understand music. Yet by a simple analogy with such well-known manifestations as sound, light, and heat, we get a better appreciation of what electricity is than in any other way. These things are familiar to us. The child knows to a great extent what light is before it learns to spell the word. Heat is essential to our existence, and we observe very slight changes in temperature most keenly. When we consider that the difference in temperature between our bodies and the heat of melting iron is about two thousand eight hundred and fifty degrees, and that these extremes are common and moderate in nature, the fact that an alteration of only fifty degrees sends us from lemon ices to fur overcoats serves to show how extremely sensitive we are to heat. As for sound, we do not need to have that defined for us. We had an inherent understanding of what it was long before we were taught that it was due to vibrations, as of the air.

Having, then, an appreciation of what light, heat, and sound are, we desire to be able to appreciate electricity in the same way. Just here the scientific knowledge of light, heat, and sound will help us to comprehend electricity in a commonplace way. Space is filled with a medium, vastly lighter than air, called the luminiferous ether. It exists not only in space, but permeates all solid and liquid bodies —in fact, everything. This ether is subject to vibrations of inconceivable rapidity. It is these vibrations that convey to our eyes the light of stars across measureless space. A difference in the rapidity of these light vibrations conveys to our eyes the sense of color. At one speed of vibration we see red, at another yellow, and at a third blue, and so on through the intermediate combinations and shades. The light vibrations in the ether are like the

sound vibrations in the air—they go through it without moving it, as a ripple passes over the surface of a lake without disturbing its occupants. The air is, however, subject to violent disturbances in the form of winds, and so the ether is subject to similar disturbances whose manifestations we call electricity. Do you begin to understand? Sound is a wave motion passing through the air. Light is a wave motion passing through the ether. Heat is a more pronounced molecular disturbance of the ether, that may affect the ether within our bodies. Electricity is as the wind of ether—a still more violent disturbance of the molecules, capable of exerting tremendous force, and of passing through solid bodies. It is tasteless and odorless, and in many ways inappreciable to the senses, but it is not at all a mystery. Sound travels without disturbing the air, and light travels without disturbing the ether. On the contrary, wind travels by disturbing the air, and electricity by a disturbance of the ether. By keeping this analogy in mind, that electricity is the onflow of ether, as wind is the onflow of air, we gain a realistic conception of this thing that we cannot see or appreciate in the way that we appreciate sound or light. There are blind insects that live, and breed, and die in caves, and have no knowledge or use for light. We have, as a race, been blind to electricity for ages. Perhaps our day is coming, and human beings may yet develop a new sense, enabling them to know what electricity is, just as the insects that do not live in caves have a sense of light.

The next point to be cleared up is as to the means by which we use this wind of ether, electricity. We know that if we confine air in a pipe and put a bellows or blower in operation at one end, the wind created will give us power at the other end of the pipe, which power we can

use for driving a fan, or operating machinery, as by means of a cylinder and piston. For electricity, we require not a pipe with a hole through it, but a line composed of a substance through which electricity travels easily, and shielded from going astray by a substance through which it does not travel or flow readily. In a copper wire we find the former, which we call a conductor. Along this wire electricity will flow as the air flows through a pipe, only very much more rapidly. The insulation or non-conducting covering of this wire serves to keep the electricity in the desired line as the walls of the pipe confine the wind. Thus we convey electricity.

If we wish to get light from this current on the wire we have but to use a very fine portion of heat-resisting wire, such as platinum, and confine it in a vacuum in a glass bulb, so that it will not burn up quickly, and when the current flows through our wire in the bulb we have an incandescent electric light. Or, if we want an arc light, we use a much more powerful current and make a slight break in the line of wire, using pieces of carbon at the point of breakage, as ordinary wire would not stand the heat. The electricity, in seeking to continue its flow along the wire, leaps across the little break or gap, and in so doing makes a manifestation of light, as the lightning does when electricity leaps from one cloud to another, or to the earth.

How do we get the current or etheric wind that flows along our wire? It is by utilizing the law that electricity makes a temporary magnet of iron when it flows around it. Thus, if we wind a bar of iron with a coiled wire, and pass a current through that wire, it may exert a magnetic force and draw towards it an armature. If the current be then shut off the armature may continue on in a circuit,

and as it comes around to the original point of starting the iron bar is again magnetized by turning on the current, and draws the armature along, producing rotary motion. This is the principle of an electric motor. And we get the electricity for operating our electric motor by using a similar machine in a reverse manner, which machine is then called a dynamo or generator. In this dynamo we move an iron bar to and fro, or more commonly in a circular path, towards and away from a bar of iron about which a wire is coiled, and the coil becomes stored with electricity, and is a temporary magnet. We may use a steam-engine to move our armature and set up this current, which may be led from the generator to an electric motor to do work, as in running the machinery of a factory; or we may send it out on a trolley-wire to be conveyed to the motors of a street-car, and carry it along; or we may electrify a wire so that it shall reproduce the vibrations of sound on sensitive disks, giving us the telephone; or send it along another wire to a little bit of a motor, that can do no better work than to make little clicks with its armature, which, properly used, according to the Morse code, conveys a telegraphic despatch.

It is all very simple, and easy to understand, when once you have the principles ingrafted in your mind.

Now that we have gained some appreciation of what electricity is, and how it performs the tasks which we have learned to set it, let us try to go a step farther, and see if we can discern any future uses for this most subtle of fluids, which we are just beginning to learn to use, to enable us to annihilate space, and do our will, across the trackless waters, or threading through the mazes of a hive of industry.

We have access to a fourth state of matter, of which the

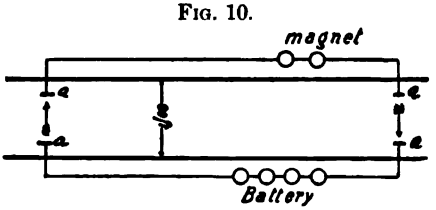
others may be given as the gaseous state, the liquid state, and the solid state. This fourth state is made up of ether, which moves with the velocity of light, and if we are ever to communicate with other worlds it will be by this medium. As we can never run a wire to another sphere, we must, then, learn to send our currents by other means. It is just this thing which eminent electricians tell us is possible. Nikola Tesla has demonstrated that it is not necessary to have a return wire to connect a motor and its generator, or even to use a wire at all. He says, "It is not necessary to have even a single connection between the motor and the generator, except, perhaps, through the ground; for not only is an insulated plate capable of giving off energy into space, but it is likewise capable of deriving it from an alternating electrostatic field, though in the latter case the available energy is much smaller."

When we have learned to make practical use of this principle we shall have no need to transmit power in any other way. He says, further, "We shall have no need to transmit power at all. Ere many generations pass, our machinery will be driven by a power obtainable at any point of the universe. . . . Throughout space there is energy. Is this energy static or kinetic? If static, our hopes are in vain; if kinetic—and this we know it is for certain—then it is a mere question of time when men will succeed in attaching their machinery to the very wheel-work of Nature."

Already we know of one practical means of conveying useful intelligence by electricity without a connecting wire, and it is reasonably sure to come into use before long. Suppose the problem is to convey information between two passing ships, on a dark and stormy night, from a distance at which neither can see or hear the other by or-

dinary means. The roaring winds drown the powerful fog-horns, and the dense mist shuts out the strong arc lights. Suppose, now, that each of these vessels has an insulated wire running from stem to stern, and dipping into the sea at either end. Connected with each wire is a generator capable of producing strong, rapidly alternating currents of electricity. Also on each wire is a receiving telephone. The sounds from one vessel will then create electric undulations through the ether that pervades the water, and be conveyed for miles, despite the racket and the raging of the elements, to the ear of a listener at the telephone of the other vessel. By such means can our ocean greyhounds continue at full speed in the storm and darkness with the same safety that they fly onward in the warm sunshine of a June day.

FIG. 10.



MORSE'S METHOD OF TELEGRAPHING ACROSS A RIVER WITHOUT WIRES.
a, *a*, *a*, *a*, copper plates.

The proof that this is practicable, and not mere theory, has been shown many times. It was done by Morse across a small river, and since his time at greater distances. An experiment was tried in the Bristol Channel a couple of years since, at Lavernock Point, which is more than three miles from Flatholm Island and five and a half from Steepholm Island. Wires six hundred yards long were laid at each place, the ends extending into the water below low-water mark. A steam-launch in the

Channel was also supplied with such a wire. A two-horse engine was made to work an alternator, sending one hundred and ninety-two complete alternations per second with a voltage of 150, and a maximum strength of fifteen amperes. These alternating currents were broken into Morse signals by a telegraphic key. Ordinary telephone receivers were used on the secondary circuits. The experiment was found wholly successful between Flatholm and the shore, and a number of messages were enchanged. On the more distant island the sounds telegraphed were heard too indistinctly to be interpretable. It was found necessary to keep the line that entered the water near the surface, as with deep submergence the sound was altogether lost. This method, if brought into general use, would be very serviceable in warning ships of the presence of lighthouses.

The telectroscope, a hypothetical instrument invented by Leon le Pontois, is even more wonderful. By its aid he expects to make visible that which is at the other end of the wire, just as we now hear what goes on at the other end of the telephone. Though the instrument is only in a proposed stage as yet, it is clearly conceived on scientific principles, and is a reasonable possibility of the near future. He proposes to use a rotating disk, having say twenty holes in its periphery. As this disk rotates, it will convey to the observer a continuous picture of the light thrown towards these holes from a receiving instrument constructed to vibrate in accord with the light vibrations carried over an electric wire from a corresponding instrument that receives the image at the far end of the wire. The entire description of the apparatus is too technical for popular reading, but the following from the pen of the inventor throws further light upon the operation:

"With the apparatus, it can be easily understood that, if the disk is caused to revolve, each of the rays of light forming the picture will successively set in the line currents of varying strength. These currents act at the receiving apparatus upon a microphonic relay acting on the telephone receiver, modified by the addition of a narrow chamber placed between the disk and a cover hermetically closing the telephone.

"One of the chambers is full of oxygen, brought in by a pipe, and the other is full of hydrogen. On the top of the covers is tubing properly adjusted and provided with regulating valves. The two gases are brought under pressure near the surface of a cylinder of carbonate of calcium.

"The variations in the strength of the current of the microphonic relay cause pulsation of the diaphragms. But those pulsations, even if they are of a molecular nature, impart to the molecules of the gas an excess of speed, causing proportional variations in the intensity of the oxyhydrogen light. A lens and a reflector concentrate the light on a ground glass or screen after having previously passed by one of the perforations of a disk absolutely similar to the disk placed in the transmitting apparatus.

"Then, according to the position occupied by the perforation on the surface of the disk, the beam of light passing by this point makes a more or less luminous point at some place on the depolished glass.

"But as the two disks are revolved synchronously by the two pulsating current motors, whose pulsations are controlled and even created by the vibrations of a tuning-fork, when the light of the receiver passes through a certain perforation of the receiving disk one of the rays of light

emitted by the object passes by the same perforation of the transmitting disk. If the disk turn slowly, each ray of light emitted by the different points of the object placed in the field of the transmitting apparatus is converted into an electric current of proportional intensity, which current is reconverted at the receiving apparatus into a beam of light of proportional intensity, and if a sensitive plate were substituted for the ground glass, a picture would be taken of the object placed in view of the transmitter after a complete revolution of the disk. But if the disks are revolved at a rate of ten revolutions per second, each point of the depolished glass is more or less luminous or dark ten times a second, and on account of the persistence of vision the retina is not affected by the successive disappearance of the points, which taken together reproduce exactly the object placed in view of the transmitter.

"It does not matter even if this object moves or not, because the image of the receiver is constantly modified by its movements."

Let us hope that this talented inventor may live to see his instruments perfected and in daily use.

The greatest money harvest, however, awaits the inventor who discovers a satisfactory method of converting coal directly into electrical energy. At present, Tesla's oscillator comes nearer this goal than anything developed, yet all electrical engineers are convinced that there will be discovered some simple and less wasteful method than that of burning the coal under a boiler to make steam, passing the steam through cylinders to make use of its pressure, and from the power thus derived driving a dynamo to send out a current on the wires. Some day a genius will devise a machine in which the burning of a gas flame at the bottom will enable electricity to be taken from the top, and we

shall secure twenty times the power from a pound of coal that we now receive. Then we can build steamships that will cross the Atlantic in three days or circumnavigate the globe inside of one month. Then we shall have electric locomotives that will make the run over perfect railways between our large cities at a speed of one hundred and fifty miles an hour—a speed limited not by the capacity of the locomotives, but by the ability of the steel mechanism to avoid dismemberment by centrifugal force. This is not visionary talk, but the serious conclusions of men who have given more thought to these subjects than their fellows.

The power which we have just begun to draw from Niagara, and upon which we may draw from every waterfall, has a source further back than gravity. The sun's rays give out a heat that results in the gathering of the waters that descend the falls. The same luminary supplies the inhabitants of the tropics with more heat than they require. May we not some day draw upon this heat by electrical wires, and soften the icebergs of the frozen North? As Sidney F. Walker has aptly put it—

"If what we know as electricity be a form of molecular motion at a lower rate than the slowest of the invisible heat waves, the day on which it becomes possible to reduce the rate of the molecules, when vibrating under the influence of heat, directly until their motion corresponds with the rate we know as electricity without the at present necessary repeated transformations, an enormous stride will have been made towards neutralizing the inequalities of climates on our globe.

"It is some years since Professor Oliver Lodge added to Lord Rayleigh's work the discovery that floating dust particles might be aggregated in the same manner as the rain-

drops are by discharges of static electricity. Is it too bold, wickedly bold, to hope that in the future, by means of electricity, we may be able, at least in part, to control our seasons? Why need we have a dry summer, as in 1893, when the moisture is present in the atmosphere, and can be made to descend? Why need we have superlatively wet seasons if the atmosphere is not allowed to retain a superabundance of moisture, when it may be caused to discharge its cargo when desired?"

There is good reason to believe that before many years the submarine ocean cables will be available for telephony, and that the sounds of the human voice may be heard under the broad Atlantic. Ocean telegraphy is undeniably slow, about twenty-five words a minute being all that can be obtained. The gutta-percha insulation of the cable retards the rate of signalling, and various ingenious devices have only partially improved the speed. No electrician will be found, however, who doubts that, in spite of this retardation, which now makes telephony impossible in a submarine cable, a time is coming when the telephone will triumph over the difficulty. Already Dr. Silvanus P. Thompson has announced that he believes that he has found a way to overcome the obstacle, by introducing a series of shunts in the cable, and dividing the cable-wires into sections of about eighty miles. His scheme is very technical, but is endorsed by other eminent electricians.

It is well known that, notwithstanding the moderate cost of the arc electric light, it is obtained by a most wasteful method. Only one per cent. of the energy in the current goes to make the light! The remaining ninety-nine per cent. is lost. The waste of heat begins in the furnace, and there is loss by friction, leakage, lack of balance, etc., in every part of the steam-engine. The best of

engines develop but a small per cent. of the heat energy from the coal. There is great waste by belt friction in connecting with the dynamo, and the dynamo itself wastes about ten per cent. Thirty per cent. more is lost on the wires of the system, and of the small remainder that reaches the arc light, ninety-nine per cent. is dissipated in passing the carbons. We look to Tesla's oscillator to save the wastes in the engine and belts, but for the saving of that ninety-nine per cent. we have not yet found a means.

We have noted that light is the result of etheric vibrations of high pitch, and it should be added that they are much higher than the heat vibrations. If, then, we have to make light by beginning with nothing and continuing through all the lower vibrations until we get to the light vibrations, we are wasting a great deal of energy. Yet that is just what we are doing. If we must needs do it that way we require a light-producer that shall acquire the higher vibrations in a marvellously short space of time. Light is the product of etheric vibrations whose rate is estimated to be about five hundred trillions a second. It is a difficult task some inventors have set themselves, to "catch on" to this mighty exhibition of energy, but Edison and others tell us that it can be done.

Mr. Tesla believes that the production of a small electrode or terminal button is necessary to the production of a satisfactory incandescent light. He says:

"The intensity of the light emitted depends principally on the frequency and potential of the impulses and on the electric density on the surface of the electrode. It is of the greatest importance to employ the smallest possible button, in order to push the density very far. Under the violent impact of the molecules of the gas surrounding it, the small electrode is, of course, brought to an extremely

high temperature, but around it is a mass of highly-incandescent gas, a flame photosphere many hundred times the volume of the electrode.

"To whatever kind of motion light may be due, it is produced by tremendous electrostatic stresses vibrating with extreme rapidity. . . . Electrostatic force is the force which governs the motion of the atoms, which causes them to collide and develop the life-sustaining energy of heat and light, and which causes them to aggregate in an indefinite variety of ways, according to nature's fanciful designs, and form all these wondrous structures we see around us; it is, in fact, if our present views be true, the most important force for us to consider in nature."

We can safely leave such problems in the hands of such geniuses as Edison, Tesla, Thompson, and Le Pontois. Indeed, let us be thankful that it does not fall to the common lot to be obliged to solve these questions for ourselves. Such work requires godlike genius and an entire devotion to one line of research. Some day the world will realize all the advances in electrical science that have been hinted at here, and that probably before the close of the twentieth century. The favored ones who live in that time will no doubt dream of possibilities that are unborn to living minds. It seems not unreasonable to presume that the Creator designed man to eventually master all knowledge. *Sic itur ad astra!*

THE KINETO-PHONOGRAPH.

Professor Edison's Invention for reproducing continuously Sights and Accompanying Sounds—Its Wondrous Possibilities.

IN 1887, Thomas A. Edison set himself to work to develop the idea found in the zoetrope, and to perfect it so as to reproduce to the eye the effect of human motion by means of a swift and graded succession of pictures, and of linking these photographic impressions with the phonograph in one combination so as to present to the eye and ear simultaneously the sounds and sights of events gone by. The zoetrope contains a cylinder, ten inches wide and open at the top, bearing a series of pictures on the lower portion of its interior. These pictures represent a sequence of moving events, as wrestling, or the tumbling of acrobats. The pictures are jerked along one after another so as to give a clumsy suggestion of continuity of action in one picture. Instantaneous photography, as developed by Muybridge and others, furnished the opportunity of making much more perfect pictures for continuous reproduction, and Mr. Edison, with infinite pains, produced an apparatus to exhibit a series of such photographs with such rapidity as to deceive the eye and present an apparently perfect reproduction of moving scenes, and which might be exhibited in connection with the phonograph. The different forms of this invention he terms the phono-kinetograph, phono-kinetoscope, kinetograph, and kinetoscope, while the combination of the whole is the kineto-phonograph. For the facts concerning these the writer is indebted to a pamphlet written by W. K. L. Dickson, who was associated with Mr. Edison during the perfecting of the devices. The illustration is from the same source, by the courtesy of Mr. Dickson.

The experiments which resulted in giving the world this series of apparatus lasted through a period of six years. The first photographs taken were of microscopic size, and were mounted on a cylinder like that of the phonograph. The idea was to rotate the cylinder in unison with the phonographic cylinder, and operate them synchronously. At first it was found impossible to secure clear-cut outlines for the minute photographs. Then a new sensitive coating was tried for the cylinder, which gave an exaggerated coarseness. This difficulty was obviated by enlarging the size of the photographs. These larger pictures were taken on the periphery of a disk, which was swiftly rotated, and by turning on an electric light for inappreciably short intervals a series of suitable pictures was obtained.

It was deemed necessary to produce these photographs on the inside of a drum. A highly sensitized strip of celluloid, half an inch wide, was tried, and subsequently superseded by a strip an inch and a half wide, with margins on the edges for perforations at close and regular intervals. These perforations were designed to enable the teeth of a locking device to hold the film steady for nine-tenths of the one forty-sixth part of a second, when a shutter opened rapidly to admit the beam of light, causing an image to be photographed. In the remaining one-tenth of the forty-sixth part of a second the film was jerked forward, only to be again arrested for the shutter to admit another beam of light, so that forty-six impressions are taken per second, or two thousand seven hundred and sixty a minute. This speed is sufficiently fast to deceive the eye with the impression that a continuous moving scene is being viewed. Despite the required forty-six absolutely dead stops per second, the speed maintained is actually twenty-six miles an hour.

Positive pictures were formed from the negatives thus obtained by passing the negatives through a machine, in conjunction with a blank strip of film, which after development is placed in the kinetoscope for the benefit of those who peep in. The next step was to reproduce this series of pictures in exact harmony with accompanying sounds. It was obviously necessary to take the pictures at the same time that the rotating cylinder of the phonograph took in the sounds. The minute stops and starts of the picture-cylinder rendered this a task of almost insuperable difficulty, which was conquered in a manner too intricate and complicated to detail here. Suffice it to say that the synchronous motion was established, with all the perfection of result hoped for.

The kineto-phonograph, or combined apparatus for reproducing sights and sounds, as in a theatre, is well shown in the accompanying illustration. The actors in the kinetographic theatre are obliged to group themselves as closely as possible, and they are either blinded by the direct rays of the sun or exposed to twenty arc lamps so arranged with reflectors as to give some fifty thousand candle-power.

The kinetoscope as best known to the public of to-day is a nickel-in-the-slot affair for reproducing dances and boxing bouts. Such is not its true mission, however. It is meant to present reproductions of grand opera and the higher class of enduring theatrical performances, with the action and the sounds in unison. Such results may be made more life-like by viewing the pictures through a magnifying-glass or projecting them upon a screen. Woodville Latham has experimented with methods for reproducing in magnified form on a screen the pictures as seen in the kinetoscope. He has been successful, devising a means for making the performance continuous when de-

sired. He calls his apparatus the eidoscope, and has given exhibitions in New York city and elsewhere, throwing nearly life-size moving pictures upon a screen.

The possibilities of the kineto-phonograph are almost endless. It may bring to our doors the sights and scenes

FIG. 11.

THE KINETO-PHONOGRAPH.

which heretofore have been obtainable only by travelling in distant lands. It will carry the eloquence of coming orators and the voices of gifted singers to the ears of waking mortals long after the original voices are hushed in death. It will bring to the bedside of the invalid all manner of amusement suited to his fancy. It will give

to all the privileges now open only to those few who gaze through the large telescopes at the wonders of the planets. The student of history in the year 5000 will be able to drop into some public resort and select from a catalogue some stirring event of a by-gone age, and lo! the scene is before him as real in its action as on the day of its happening. He may gaze on the beauteous women who have been famous because they outrivalled the beauties of their day; he may view the tremendous carnage that resulted from the last war; he may see the volcano belch forth its fires or listen to the tornado's wrath. The ghosts of all the past since 1895 will be at his beck and call as easily as now we turn a page of history. As Mr. Dickson eloquently puts it—

"What is the future of the kinetograph? Ask, rather, from what conceivable phase of the future can it be debarred? In the promotion of business interests, in the advancement of science, in the revelation of unguessed worlds, in its educational and re-creative powers, and in its ability to immortalize our fleeting but beloved associations, the kinetograph stands foremost among the creations of modern inventive genius. It is the crown and flower of nineteenth-century magic, the crystallization of eons of groping enchantments. In its wholesome, sunny, and accessible laws are possibilities undreamt of by the occult lore of the East; the conservative wisdom of Egypt, the jealous erudition of Babylon, the guarded mysteries of Delphic and Eleusinian shrines. It is the earnest of the coming age, when the great potentialities of life shall no longer be in the keeping of cloister and college, sword or money-bag, but shall overflow to the nethermost portions of the earth at the command of the humblest heir of the divine intelligence."

THE ELECTRIC STORAGE-BATTERY.

Success of the Chloride Accumulator due to a Mechanical Change in the Plates—An Auxiliary for Light and Power Stations.

THE ideal system of electrical propulsion is by the utilization of a battery in which the power is stored so that it may be carried on the vehicle, always ready for use and involving no expense when idle. By the employment of this method outside wires are dispensed with, and the vehicle can go anywhere on a good road until the power in the battery is exhausted. A vast amount of money has been expended in applying this system of propulsion to street-cars. There have been numerous companies organized all over the world, who have placed their cars on the market and proclaimed great things for them. As a rule, they accomplished all that was expected of them in the way of drawing certain loads at desired speeds, but were all subject to two fatal objections—the batteries were too heavy, and the plates broke down and buckled so frequently as to prove disastrously costly.

A brief description of their use in connection with the Julian system will suffice for all the others. This was tried on Fourth Avenue, in New York, in 1889. The batteries were placed under the seats, and recharged from a dynamo every four or five hours. Each car had two sets of batteries, and exhausted ones were taken out and charged ones inserted, at a convenient station, with no appreciable loss of time. The cars were given the equivalent of thirty-five horse-power at the start, and were expected to consume twelve horse-power during a trip. A car was run into the station, panels at the ends of the seats were removed, and fresh batteries taken from shelves within reach. The exhausted batteries were placed on a shelf, and the whole

number automatically shifted to the generator to be recharged. The motors under the cars were flexibly connected with the batteries, and the large margin of power was considered ample to offset accidents. But the plates in the batteries would become short-circuited and buckle, and cease to be of use, and so the plant was finally abandoned.

This unfortunate result, with many others similar, created the public impression that the storage-battery would never be a success; but about the same time that the cars were being abandoned on Fourth Avenue a company in Paris and another in Philadelphia were experimenting on parallel lines towards the goal of success. It was discovered that a fusion of chloride of zinc and chloride of lead, when properly treated, would produce pure lead in a crystalline form, in which the molecules are arranged in a perfectly symmetrical order instead of fortuitously, as in the mechanical mixtures which had theretofore constituted the active material of the plates in storage-batteries. This discovery was rendered of commercial value only after a long series of experiments and improvements, conducted on somewhat different lines, in Paris by the Société Anonyme pour le Travail Électrique des Métaux, and in Philadelphia by the Electric Storage-Battery Company. The Paris company completed its experiments and went to manufacturing in 1889, and by the end of the following year had supplied the city of Paris with storage-batteries for a lighting-plant comprising over two hundred thousand sixteen-candle-power lamps. The Philadelphia company did not complete a battery fit for the market until 1892, in which year it sold its European rights to a London syndicate, and entered into a triplicate alliance with them and with the Paris company to control the perfected

storage-battery throughout the civilized world. To perfect its grip in America the Philadelphia company bought up all its competitors in the United States.

The French company are operating three lines of street railway in Paris, and are to operate others in Marseilles, Nice, and Avignon. They operated the cars of the Intramural Railroad at the Lyons Exhibition in 1894.

The advantages of the chloride accumulator, as this perfected storage-battery is called, can be best conveyed by a short description of the Paris cars, which have been in operation three years. There are two lines running from Paris into the suburb of St. Denis, with a charging station and a depot at the latter place. The generating plant consists of three one hundred and fifty horse-power boilers and three engines of corresponding capacity. The company has twenty-five cars, each fitted up complete with one hundred and eight chloride cells specially designed for traction purposes. The life of this latest type of cells has not as yet been ascertained, since none of them are as yet worn out, but it is thought that it will prove to be between twelve thousand and twenty thousand car-miles. Each cell is fitted with eleven plates, and fifty-two batteries are used on the line, giving a total of five thousand six hundred and sixteen cells and sixty-one thousand seven hundred and seventy-six plates.

The work that has to be performed is severe, the gradients being as much as one in twenty-five for considerable distances. There are also numerous short curves. The cars are of a heavy type, with inside and outside seats, and constructed to carry fifty passengers, their total weight with full load being about fourteen tons. The weight of a battery of one hundred and eight cells, with which each car is fitted, is, approximately, two and a half tons, com-

plete with all accessories, acids, and boxes, and the capacity of the same is such as to be sufficient to run the car for a distance of about forty miles under the severe conditions of grade and curve before mentioned. As would naturally be expected, it is found that the best results in efficiency and life are obtained by running a car but twenty-five or thirty miles before returning it to the depot to have the cells recharged. The work performed daily upon these lines is equivalent to fifteen hundred and fifty car-miles.

A complete understanding of just what this perfected accumulator is will be of interest, as showing why this form has triumphed where all others failed. The elements are made of cast tablets, or pastilles, of a salt of lead, enclosed in a dense frame—composed of lead and antimony—cast around them under heavy pressure. This plate of lead salt so framed is then reduced electro-chemically to pure metallic lead. This gives a plate composed wholly of metallic lead, partly in compact form, partly in minute crystalline subdivision, differing only from a plate of cast or rolled lead in that some of its parts are of a crystalline character—a difference purely mechanical. This is the same plate that Planté used, except for this important mechanical difference. These plates, requiring oxidizing, are then put with alternate lead plates in an electrolytic cell, and a current is passed through them for a sufficient time to convert the pure crystalline metallic lead into peroxide of lead. The principle is well explained in the following paragraph from the proceedings of the Franklin Institute:

"It is well known that in a crystalline form the molecules of matter are arranged in a different order from what they are in any mechanical mixture. In the mechanical mixture the aggregation of the atoms is strictly fortuitous —that is to say, it is a mere question of chance how they

are arranged, and they have no cohesion among themselves beyond that which is given to them by the cementing mixture which holds them together. In the crystalline form, however, all this is changed: the molecules of the body are arranged in perfect symmetrical order, and they are held together by molecular affinities which regulate the order of their distribution and secure the coherence of the mass. It is quite true that the material is denser unless some means are employed to modify the density; but although this is the case, the molecular channels which exist in the interstices of the crystals are arranged in as regular order as the molecules of the crystals themselves."

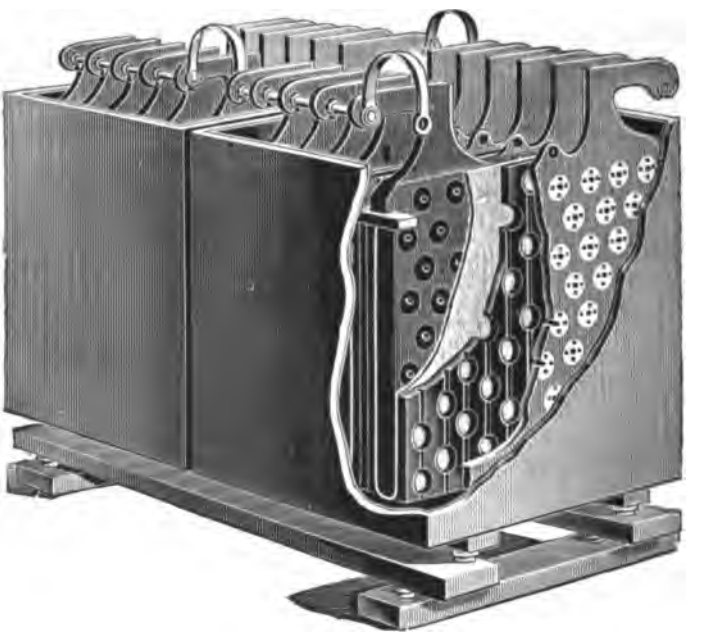
In the illustration it will be observed that there is a negative plate, with round tablets of active material, which have perforations that permit the circulation of the battery fluid. Next is a separating piece of wood, that has been soaked in some insulating compound, and that has holes opposite the tablets in the plate. Grooves connect these holes, to permit the circulation of the liquid and to afford a passage for gas. A thickness of asbestos cloth is seen next enwrapping a positive plate, which is made heavier than the negative. This asbestos prevents any active material which may be loosened from falling where it can short-circuit the plates.

The discovery and successful application of this principle has enabled the production of an accumulator with a high rate of charge and discharge without injury to the plate, a high capacity of storage, and the maintenance of the voltage through a very large percentage of the capacity. Along with this there is also a very greatly increased durability; and the fact that the same number of ampere hours can be stored in half the weight of plates, as against every other previous system, not only makes their introduction a dis-

tinct era in electrical science, but opens up an increasingly wide field for their use in every-day life.

Although it is very encouraging to observe that the chloride accumulator is in successful use, it must be borne in mind that for the operation of independent tram-cars it

FIG. 12.



THE CHLORIDE ACCUMULATOR.

will always be more expensive than the trolley, since there is a necessary waste of electricity in storing and withdrawing the charge. Nevertheless, this form of storage-battery has found another and a larger field as an auxiliary to the trolley.

A storage-battery operated in connection with the power-

plant of a trolley road acts not only as an auxiliary to the dynamos, but also as a regulator of the load on the generating apparatus, allowing it to run at a steady and efficient point, and protecting it from the great strains due to grades and to the starting of a number of cars at one time, etc. A battery has been installed for this class of work in the Isle of Man, where its successful operation has fully demonstrated the economy of this system. The first installation of the kind in this country was made in the city of Merrill, Wisconsin, in January, 1895. The plant there consists of two hundred and forty chloride accumulators, with a capacity of five hundred ampere hours at a fifty-ampere rate of discharge. The batteries are divided into four series of sixty cells each, connected to a switch-board and so arranged that cells may be connected to the railway—two hundred and forty in a series—or to lighting circuits in two parallel series of sixty cells each. On January 4, when the battery was connected to the railway circuit, the great improvement in the running of the cars was immediately noticed by all, but it was at night that the contrast was most apparent. Instead of one dimly-lighted, slow-running car, two brilliantly-lighted cars were operated at the highest speed allowable on the streets. Instead of a succession of sharp peaks, the voltage curve of lighting became practically a straight line. On several occasions the cars were operated by the battery alone for several hours at a stretch, thus allowing in the daytime the entire shutting down of the power-plant and at night the full capacity of the power for lighting. This installation clearly demonstrates the great value of storage-battery installation in connection with light and railway plants. A new plant can be put in at a lower cost with a storage-battery than without, because less reserve power is required

of the engines, boilers, generators, etc., and established plants can be increased in capacity by this means at trifling cost.

Tommasi's multitubular storage-battery, which has been introduced in Paris, is another practical and efficient form of accumulator, free from the defects of the early types. The electrodes are formed of perforated tubes of lead, celluloid, or the like, the bottom being closed by an ebonite plate, in which is fixed a lead conducting-rod. Oxide of lead fills the intervening space of the tube. By using metallic contacts between the rods of the positive and negative tubes the current is spread through the entire mass, producing a chemical circuit with uniform action. The tubes do not expand, and the active material is so shut in that it cannot fall and cause short-circuiting.

The storage-battery is coming into use in many minor fields, and the more important of them are noted below.

Battery locomotives for mill purposes have recently attracted a good deal of attention. Locomotives of this character have been used in this country with great success, particularly in the works of Norton Brothers, near Chicago, where locomotives operated by chloride accumulators run through the mills, in and out of the rooms, and about the yard, hauling trains of cars loaded with tin-plate. Battery locomotives are also the ideal method of haulage in mines, and without doubt will be adopted in the very near future.

An interesting application that has not progressed very far in this country is the propulsion of carriages, omibuses, delivery-wagons, etc. This delay is largely due to the fact that the roads in the United States are far inferior to those of the long-settled countries of Europe. However, we have some progress to record in these vehicles. An elec-

trically propelled carriage has been running in the parks of Chicago supplied with chloride accumulators, and in Boston a similar vehicle has recently been equipped. The Franklin Electric Company, of Kansas City, has just made a motor for a carriage to be run by twenty-five chloride cells. Another vehicle, designed by Morris & Salom, has been running successfully about the streets of Philadelphia. The Holtzer-Cabot Electric Company, of Boston, have built an electric carriage in the shape of an English drag, with three seats, carrying eight to eleven persons. This carriage, like the others, is run by the chloride storage-battery.

The electric launches used at the World's Fair in Chicago were run by these same accumulators. The attractive feature in an electric launch is the fact that, besides being free from noise, smell, and danger, no engineer or attendant of any description is necessary to operate the boat, and wherever a trolley, an arc circuit, or an incandescent circuit is available, the batteries can be recharged with very little trouble and expense.

Electric light and power stations cannot afford to be without accumulators. The French company has equipped some twenty-six central stations with the batteries. The Edison Illuminating Company, on Twelfth Street, New York, has introduced a large plant of chloride accumulators. Another installation has been in operation since 1893 in the central station of the Germantown (Pennsylvania) Electric Light Company. Many public institutions also use them.

A great many hundred storage-cells have been sold for train-lighting. In some cases, where conditions permit, batteries are removed from the train for charging, and when on the train operate the full complement of lights. In other

cases, a smaller battery, permanently located on the car, is charged from a small dynamo connected to and operated from the axle of the car. This latter application promises to do away with all objections raised against former methods of electrically lighting trains. An official of the Intercolonial Railway of Canada experimented with the chloride accumulators furnished that road, and short-circuited one cell fifty-seven times, each time for a period of an hour and a half, without being able to damage it.

Yacht-lighting is a field in which storage-batteries are indispensable. On a vessel the noise of a dynamo in operation is intensified, and when the machine is run throughout the night becomes very objectionable. To keep up steam simply to run a dynamo when the vessel is in harbor is expensive. A storage-battery obviates these objections. A large battery was installed in 1894 on the "Marguerita," owned by Colonel A. J. Drexel.

The lighting of carriages, advertising wagons, etc., is another field in which chloride accumulators have been adopted. A large number of private carriages have been so equipped, and theatre-advertising wagons are beginning to use them. A bicycle lamp operated by the same means has been placed on the market. Similar lamps are used in oil refineries by the men who go into the retorts for making repairs, and who have to encounter explosive gases. No doubt they will come rapidly into use among miners also.

The laboratories in many institutions of learning are fitted with the chloride accumulator, among them Yale, Harvard, Columbia, and Pennsylvania.

For medical and surgical work these outfits consist of two chloride accumulators, arranged to give two or four volts and five or ten amperes. They are used for cautery

work, the lighting of small lamps, as for examining the inner ear, and the like.

Accumulators are also used for operating dental drills and for heat-regulating devices in hotels and large office-buildings. Being considered absolutely reliable, they are used in several of the large railroad-yards of this country to operate the switches and signals. The kinetoscope, phonograph, and graphophone are all operated by these accumulators. Also the range-finders used in coast defence to determine the range of guns.

The chloride accumulator is used in telegraph work, the Western Union and the Postal Telegraph Companies having installed a number of plants. Among the uses to which the battery is put in New York may be mentioned the installation, at 16 Broad Street, of a battery plant used in the operation of stock-tickers. The battery is in use in the telegraph service of numerous railroads, and has been generally adopted by the telephone companies throughout the United States.

By the use of the accumulators, in connection with the process of electroplating, the work may be kept going on for twenty-four hours a day, the batteries charged by the dynamo, when in operation, being thrown into circuit when the dynamo is shut down. As the batteries do not require attention when discharging, but one shift of men is required for twenty-four hours' work.

The accumulators are also serviceable for automaton pianos, sewing-machines, or any other domestic mechanism requiring small power. In fact, the field is so wide that there is no telling where it will end, and whether we shall not all carry our pocket-accumulators before a score of years has passed.

ELECTRIC PLEASURE-BOATS.

The Development of Storage-Battery Propulsion for Launches—Proposed Novel Ferry-Boats.

SUMMER outings have come to be a necessity with the American people, and a vivid interest is displayed in anything that affords more enjoyment to tired workers during the vacation period. Pleasure-boats have been in increasing demand for some years, and if they were as uniformly cheap as bicycles they would be nearly as common. The electric launch, which first came into general notice in the United States at the time of the Columbian Exposition, has proved sufficiently low in price and efficient in practice to cause a boom in its manufacture. In many respects the electric launch is peculiarly suited to pleasure excursions. Sails and steam-power both involve a certain amount of labor or the presence of a hired crew, neither of which is agreeable to excursionists. The storage-batteries of the electric launch, on the other hand, yield up their power on the turn of a little switch that a child can operate; they involve the use of a current that does not give an unpleasantly severe shock; and they cannot blow up or blow away. There is no smoke, dust, or dirt about them, and the mechanism is so simple that it can be placed under the seats, etc., leaving almost the whole boat available for the use of the occupants. The running expenses are small, and there is no cost for fuel-supply when the boat is not running.

A Frenchman named Trouvé may be called the father of storage-battery boats, since he built the first really practical crafts of the kind. At the Paris Exposition of 1881 he exhibited an electric boat on the Seine, driven by a propeller, directly over which he mounted a small motor,

connecting the two with a vertical chain. He used fluid-batteries, which were practical though comparatively costly to run. M. Trouvé also built a stern-wheeler—that is, a boat with two paddle-wheels set in the stern—as some river-boats are now built for shoal-water navigation.

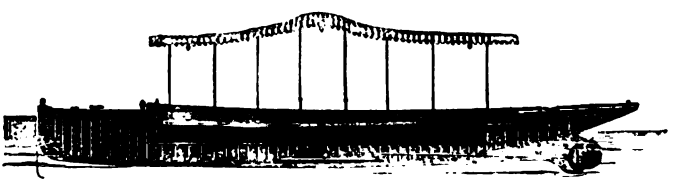
An Austrian engineer, Anthony Reckenzaun, designed a number of practical electric boats in 1882 and later. He built a twenty-five-foot launch that carried forty-five accumulators and made a speed of eight knots. In 1883 the Yarrows firm of English ship-builders scored the next advance, building a forty-six-foot launch, carrying seventy accumulators, and showing a durable speed of eight miles or more per hour.

These boats were used in England some time before they became known in America. The slow development of the storage-battery hindered their progress at the start. Five years before the Columbian Exposition a number of the electric launches were in regular use on the Thames River, and a little later on Lake Windermere, in Lancashire. The largest of these was christened "Viscountess Bury," and accommodates seventy passengers, though only sixty-five feet long. She has a ten-horse-power motor and a bronze propeller. She rents for sixty dollars a day, including a crew, so that a party can club together and secure a day's outing in her on the water for only a dollar a head. Smaller craft of the same sort on the Thames rent as low as fifteen dollars per day, including the services of a deck-hand, and minor charges. The larger sizes of such boats are capable of making a speed of fifteen or sixteen miles an hour in spurts, and have a durable speed of nine or ten miles an hour. The regulations on the Thames restrict them to six miles an hour, so that the enjoyment of travelling in them is of a decidedly placid nature.

Doubtless one reason why the boats were introduced in Chicago in 1892 was because of the success met with by a small flotilla at the Edinburgh International Exhibition in 1890. Four forty-foot boats plied there during the season, carrying as high as two thousand five hundred passengers in a day, at a four-cent fare. In these launches the seats were run around the sides, so that forty passengers could be accommodated. The accumulators were arranged under the seats, so as to give ballast to the craft.

The Electric Launch and Navigation Company of New York bought the franchise for navigating the Exposition water-ways at Chicago, and ran fifty thirty-six-foot boats there through the season, carrying about one million passengers, mostly on three-mile trips, at a cost of a fraction under six cents per mile per boat. The receipts were close to half a million dollars, and, as the boats cost less than one hundred and fifty thousand dollars and were afterwards sold for about half that sum, it will be seen that, with operating expenses of only fifteen thousand dollars, there was a good margin for some one to make a profit.

FIG. 13.



ELECTRIC LAUNCH.

The illustration shows one of these boats in section. The little propeller is driven by a shaft directly connected to the motor in the bottom of the boat, the thrust-bearing being fitted with friction-balls, like a bicycle-wheel. The

motors were four horse-power, and were arranged for four speeds. Sixty-six accumulator cells of one hundred and fifty ampere hours' capacity were used, the charging requiring from four to seven hours, according to the strength of current used, and being done entirely at night. The cost of charging the batteries was about fifty-five cents a day. The method of charging was simply to run the boat into a slip at the charging station and connect the accumulators with wires to a dynamo. A small steering-wheel was placed forward, and this, with a lever-switch for turning the current on and off, completed the operating mechanism.

In 1888, Reckenzaun, being then in America, built a launch in Newark carrying batteries good for ten hours' run of sixty to seventy-five miles. She created considerable attention about New York harbor, and later at San Francisco. She was lighted with incandescent lamps, and would carry some twenty passengers. A line was run from the factory of the Electrical Accumulator Company, in Newark, a distance of a quarter of a mile, to the water, to charge her batteries.

John Jacob Astor has taken an interest in these boats, and had two or three built for his own use. The United States navy also had a few electric gigs. One of them so interested the Grand Duke Alexander, of Russia, that the Navy Department presented him with it. Since then the boats have come into considerable favor in Russia.

General C. H. Barney, who managed the World's Fair fleet at Chicago, was so impressed with the good points of the business that he has gone into it at Boston, with other capitalists, on a very large scale, and expects shortly to have two hundred and fifty electric boats, of all sizes and styles, plying about the waters of the Hub parks and in the

harbor. This is the largest undertaking of its kind, and, if it proves profitable, will result in their utilization in all the park lakes of the country. Indeed, several other places are being provided with these pleasure-boats. New Haven has them at Lake Saltonstall, Philadelphia at Fairmount Park, Altoona at Lakemont Park, Milwaukee is to have them on the river, and Newport, Asbury Park, and other resorts are falling into line. It may be interesting to some to know that these launches cost but eight hundred and sixty dollars for a twenty-foot size, equipped with twenty batteries, and capable of four and a half to five miles an hour, which may be increased to seven miles if it is desired to race. The largest electric launch in use is believed to be the "Electron," owned by James Bigler, and run at Atlantic City, New Jersey. She is seventy-six feet long, and carries three hundred and seventy-six cells, developing a capacity of about sixteen miles an hour. Her cost is estimated at eight thousand to ten thousand dollars. Naphtha launches sell at about the same prices. They have the advantage at present of being more readily supplied with fuel, since they use a fluid which is sold in every small town, while the electric launches can only be charged in large cities or at special stations. On the other hand, the dirt and annoyance of an engine, together with the bother of running it, tend to prejudice the public in favor of the more recent invention.

An interesting row-boat is made on the principle of the electric launch. It is something of a misnomer to call it a row-boat, since it is propelled by a little battery and motor, but, as it can be rowed when the battery gives out, the name will pass. A seventeen-foot boat has a floating capacity of about nine hundred and fifty pounds, and may be expected to carry four passengers at a speed of three miles an hour,

for six or seven hours, at a cost of three cents an hour for electricity. The boat with equipment weighs four hundred and ninety pounds, and the cost is nearly a dollar a pound —a figure which competition may be expected to reduce in time. For fishing, such a boat has one rare advantage. An incandescent lamp may be attached to the battery and let down to lure the silly fish.

A few years since, Louis S. Clarke, of Pittsburg, Pennsylvania, built an electrical catamaran that attracted much attention. He used sheet-iron for the twin hulls, which were twenty-two feet long. These were set four and a half feet apart, and a platform was laid on to carry the batteries, motor, and passengers. Twenty-six cells were used, and, being the owner of a steam-launch which carried a dynamo, Mr. Clarke is able to use the catamaran as a service-boat for the larger craft, and charge it at its batteries at his convenience. The motor is of the Gramme type, made on the owner's designs. Two little switches suffice to do all the manœuvring, the tiller being the only other device with which the occupants have to bother. The speed of this curious little craft is about four miles an hour.

Mrs. F. A. Truax, of New York City, has had a novel electric boat built on her own designs, showing that there are women as well as men who can invent mechanisms. It is a four-wheeled paddle-boat, so constructed that it can be run on land on the wheels when portage is desirable. The whole affair is very light, the motor, which is of the reciprocating type, connecting directly with one of the axles, weighing but eighty-seven pounds, while the weight of the twenty-cell battery is given at sixty-four pounds, which must be a mistake, since batteries for this purpose are made of lead, and are always heavy.

Electric boats for ferries may be operated in two other

ways than those described, as is very ingeniously set forth by Messrs. T. C. Martin and Joseph Sachs, in their book on "Electrical Boats and Navigation," to which the writer is indebted for many of the facts here stated. The methods suggested appear to be the invention of Mr. Sachs, though the fact is not stated. One plan is a trolley ferry, the boat carrying a wire rope depending from a wire hung high above the river and riding along on a trolley-wheel. The wire, of course, is connected with some near-by power-station. The plan seems entirely feasible, especially for a ferry connecting with an electric railway. As the boat would require no engines, only a motor and propeller, it could be built at a very small first expense, and the cost of operating should be quite as cheap as steam. Such a ferry could be easily arranged under the Brooklyn bridge, and might relieve that structure of some of its surplus traffic. Where an overhead wire would be an obstruction to navigation an alternate plan is proposed, the wire being submerged in a cable, and picked up and run over a reel as the ferry proceeds. How the difficulty of insulating the wire in the cable, and rendering it available for use on the boat, is got over is not stated, but probably there is a way of doing it.

The future for electric boats is bright. Their development has been slower than that of electric cars, but it is just as sure. The battery principle confines them to short voyages, but for inland and coast travel they easily have the call.

THE OCEAN GREYHOUNDS.

Some Time we shall cross the Atlantic in Four Days, if Improvements keep coming—Recent Fast Liners.

THOUGH Robert Fulton is usually credited with building and operating the first steamboat in the United States, it is a fact that he was anticipated over twenty-one years by James Rumsey, of Charleston, West Virginia. In 1785 he built an eighty-foot boat in Frederick County, Maryland, the making of the boilers, engines, and metal-work being divided between several near-by concerns. The inventor did not use either paddle-wheels or propellers, but pumps, drawing in water at the bows and forcing it out at the stern. His machinery was very inadequate, as may be inferred from the fact that it only weighed six hundred and sixty-five pounds, including boiler, engine, pumps, and pipes. A public trial of the boat took place March 14, 1786, on the Potomac River. The speed made is not recorded, but of course it could have been nothing satisfactory with such crude apparatus. Rumsey was patronized by both George Washington and Governor Thomas Johnson, of Maryland, who hoped for his success principally as a means of expediting travel on the then proposed Chesapeake and Ohio Canal. This experiment is a matter of record in several State papers.

In 1805, Colonel A. E. Stevens built a launch with twin propeller-screws, arranged as in the modern ocean flyers, and driven by a small steam-engine. For some reason he failed to demonstrate the value of his device, and the screw-propeller did not come into approved use until 1840.

There were also other experimenters in the field previous to 1807, the year of Fulton's successful run with the "Clermont," but, as none of them perfected their inven-

tions, Fulton is entitled to the full measure of credit which historians unanimously accord him—that of being the first to demonstrate that steamboat navigation was a practical and remunerative method of travelling the waters of the deep. The "Clermont" was a fair-sized steamer, being one hundred and thirty-three feet long and eighteen feet beam, with a capacity of one hundred and sixty tons. Her design was scarcely beautiful, since her lines were those made familiar to us by the modern canal-boat. The side paddle-wheels were not protected by boxes, and the engine, boiler, and other machinery were also exposed. After a few experimental trips, in which she developed a speed of about five miles an hour, she was put in the docks to be enlarged, and for various alterations in mechanism which the test had shown to be necessary. Colonel John Stevens, of Brooklyn, was only a few days behind Fulton with a steamboat, and his "Phœnix" was the first steamer to venture on an ocean voyage, making a trip to Philadelphia.

Our English cousins built their first practical steamboat five years after Fulton's trip on the Hudson, Henry Bell being the designer. This boat was named the "Comet," and was forty feet long. She was propelled by a three-horse-power engine. All the early designers seemed to fail to appreciate the need of a large engine to secure a desirable speed.

In 1808 three steamboats began to make regular trips between Albany and New York, and three years later steam navigation began on the Mississippi. Within the following five years steamboat lines were established on the Great Lakes, the St. Lawrence River, and on many of the river and coast routes of Great Britain.

The first Atlantic steamship, as well as the last of the

ocean greyhounds, was built in America. The "Savannah" was originally a sailing vessel, but was fitted with paddle-wheels that could be removed inboard in bad weather, a precaution that makes one smile nowadays. She crossed from New York to Liverpool in June, 1819, in twenty-five days, creating the first record between those cities. She used her sails a part of the time, and her engines were not deemed an entire success, being afterwards removed. In 1838 the "Sirius" and "Great Western" were built on the other side, and in April of that year they crossed to New York in nineteen and fifteen days respectively. This shortening of the time settled the future of ocean navigation, and, the screw-propeller being introduced by Ericsson a little later, the trips regularly increased in speed. The first Cunarder was the "Britannia," which left Liverpool on its first trip on July 4, 1840, and reached Boston fourteen days and eight hours later.

The first man-of-war to which the screw-propeller was applied was the "Princeton," whose machinery was designed by Captain John Ericsson in 1841. The first large iron steamboat was the "Great Britain," built about 1842, though iron was used in the construction of vessels' frames as early as 1820. She was three hundred and twenty-two feet long and three thousand four hundred tons burden. She was still in use as a coal hulk in 1894. Steel began to replace iron about 1880, and now it is rarely that any other material is used for large steamers for ocean traffic. The famous "Great Eastern," built in 1854, to show what ship-builders could do when they tried, proved too big to pay dividends, and probably would have been left to rot had not the submarine cable-laying industry sprung up in time to furnish her with employment. Her enormous capacity—twenty-seven thousand tons—rendered

her suitable for carrying great lengths of cable. The most recent of the modern steamers, however, closely approach her in size, and, if the course of development keeps on, some of them will surpass her within twenty years.

The Atlantic steamers are undoubtedly the finest ocean steamers in the world, and have steadily improved since the days of the first Cunarder. There has been great rivalry between competing lines in the matter of reducing the time of crossing, and each new vessel brought out has succeeded in shaving the record. In 1868 it required nine or ten days to cross the big pond. In 1874 the "Germanic" and "Britannia" cut the record to about seven and a quarter days. In the latter part of 1893 and 1894 the "Lucania" and "Campania," twin ships of the Cunard line, took turns in reducing the record for some months, bringing the time to less than five and a half days. The vessels are almost identical in every respect, being built as near alike as possible. The length is six hundred and twenty-two feet over all; breadth, sixty-five and a quarter feet; depth from shade deck, fifty-nine and a half feet; displacement, thirteen thousand tons. The keel is a flat plate one inch thick and fifty-four inches wide. The side frames or ribs are placed thirty inches apart, and are mostly of channel section, eight by four by four inches. There are eighteen transverse bulkheads, almost as strongly made as the main shell. They are all water-tight, and the greatest distance between any two athwartship is sixty-five feet. It would be impossible to sink one of these vessels without literally crushing at least two-thirds of her bulk. The coal-bunkers and bulkheads are so arranged as to afford protection to her machinery from rapid-fire guns, should she ever encounter pirates or be called upon to do cruiser-service in time of war. Each set of engines has five

cylinders for quintuple expansion of the steam. This feature has created much discussion among engineers, and the consensus of opinion would seem to be that it remains to be proved whether anything over three cylinders is an advantage in operation. Each added cylinder is necessarily larger than the others, and requires a greater power to move its piston. The Cramps have declared in favor of four cylinders as giving the best results, but probably there are more modern vessels afloat with three cylinders than any other number. The "Campania's" high-pressure cylinders are thirty-seven inches in diameter, the intermediate cylinder is seventy-nine inches, and the two low-pressure cylinders each ninety-eight inches. The stroke of all the pistons is the same—sixty-nine inches—all being connected with the same crank-shaft. From the base of the engines to the top of the cylinders is forty-seven feet. Each crank-shaft, together with the thrust-shaft, with which it connects to send the power to the propeller, weighs one hundred and ten tons. There are two propellers, each of which consists of three blades of manganese bronze and a boss of Vickers steel. Each blade weighs eight tons. Great care has been taken to guard against any chance of the propellers racing—that is, running at enormously high speed when out of the water. There are governors on the shafts and on the engines, and, in addition, an emergency governor-gear that will stop the engines automatically if the rate of speed for which they are set is exceeded.

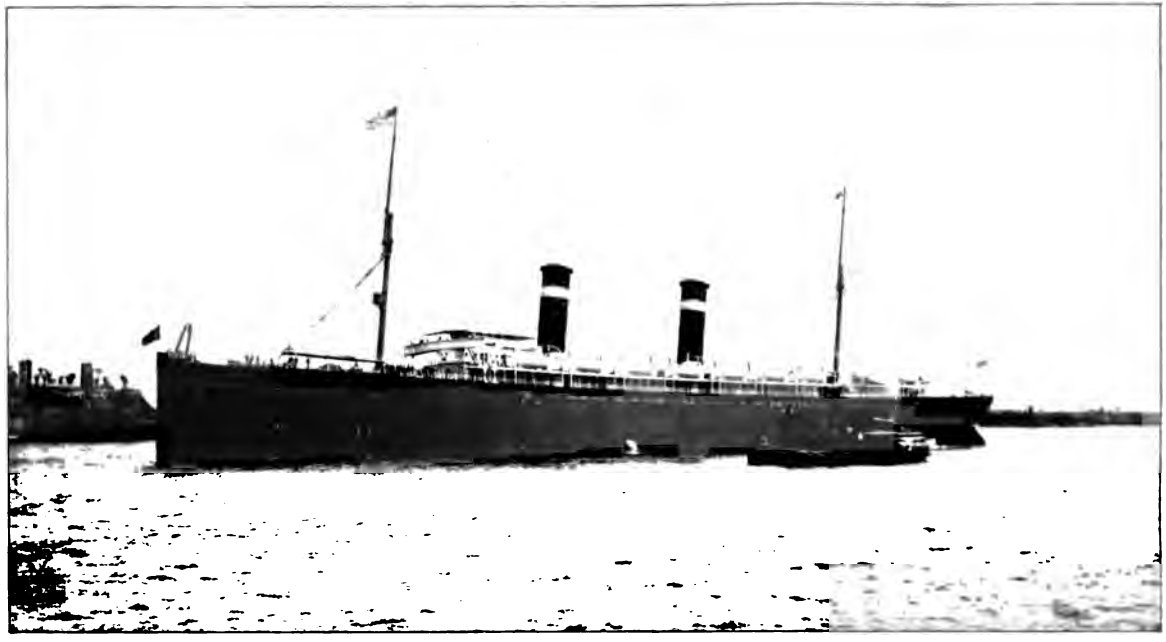
No less than a hundred and two furnaces are used for the boilers. The latter are worked at a pressure of one hundred and sixty-five pounds, and are the largest ever built for that pressure. Each of the main boilers contains a mile and a quarter of tubing, or a total of fifteen miles of tubing for the ship. There is a funnel or smoke-

stack for each of the groups of boilers, and the size of them gives some hint of the combustion below. They are oval in shape, being thirteen by nineteen feet in diameter, and over one hundred feet in length. They are made oval in shape so that they may present the narrow surface fore and aft, reducing the loss from wind-pressure when going against the wind.

A few other figures will serve to give an idea of the size and complete appointments of these vessels. The upper deck affords a promenade of a quarter of a mile before coming around to the starting-point. There are thirteen hundred and fifty electric lights, supplied through fifty miles of wires. The draught of water under load is thirty feet. There are seven levels or decks. The pumps deliver thirty-two thousand gallons of water per minute to the boilers. The boilers have a capacity of thirty thousand horse-power. The durable speed obtained is twenty-one and a half knots an hour.

Another pair of twin ships equal in interest to the "Campania" and "Lucania" is the "St. Louis" and "St. Paul," of the American line. These are the first great ocean passenger steamers built in the United States, having come from the Cramps' ship-yard in Philadelphia. On her maiden run along the coast the "St. Louis" developed a speed of twenty-two and three-quarter knots, which gives reason for hoping that the new pair may prove the fastest of their kind, though exceeded in size and power by some of the foreign builds. The "St. Louis" is five hundred and fifty-four feet over all, and sixty-three feet beam, with a depth of forty-two feet. The length is ten feet in excess of the "Paris" and "New York," and sixty-eight feet less than the "Campania" and "Lucania." The engines develop twenty-six thousand horse-power, and

FIG. 14.



THE STEAMSHIP ST. LOUIS

are of the quadruble type, expanding the steam four times. Steam is used at two hundred pounds pressure. Each engine has six cylinders and four piston-rods. In the ordinary type of quadruple-expansion engine there are four cylinders set in line. In the "St. Louis" the high-pressure and low-pressure cylinders are divided into two, each pair having a common piston. Steam enters the two high-pressure cylinders simultaneously, is partially expanded, and passes in turn to the first intermediate and the second intermediate cylinders. Then it is again divided, and passes simultaneously to the two large low-pressure cylinders. After working in these it is combined again, passing into the condensers, where it is turned into water and pumped back into the boilers to be made into steam again. Electricity is used in the lighting and to operate the ventilating plants, of which there are four. The outfit of life-boats is very complete, there being fourteen of the ordinary type, fourteen of collapsable design, and four metal, besides a cutter and a gig. The appointments for passengers are most complete and ornate.

The query is often raised, Are we not almost at the fastest limit of steamboat speed? Can we ever expect steamboats to cross the Atlantic in less than five days? Has not development in this direction about exhausted itself? The writer thinks not. If we could not hope for better engines than we have now, and had to depend wholly on increased size for more efficiency, the end would be near at hand. The present growth is limited principally by the enormous coal consumption. Some statistician has figured that a vessel could be built with a forty-knot speed if arrangements were made for one hundred and sixty thousand horse-power engines and storage for a coal consumption of two thousand tons a day. The fastest of the liners now

carries two thousand five hundred tons of coal on a trip, from which it may be gathered that the size of the forty-knot vessel would be so great as to prohibit its use with present engines. There are torpedo-boats which make thirty or more knots an hour, but it must be remembered that they do not carry coal enough to last them for more than a day's travel at that speed. It follows that if we can save coal consumption we can get more speed, for we can build the engines. Tesla has shown us that a boiler can be run at three hundred pounds pressure, and his oscillator promises a great saving in fuel. If a steamboat could be built with oscillators instead of steam-engines, and consume acetylene gas instead of coal for fuel, then we could lop off a day or two more from the time of crossing. The indications are that such improvements will be made in the future, and that in this way the time will be shortened, so that in twenty years we shall look back on the fast steamers here described as slow old tubs.

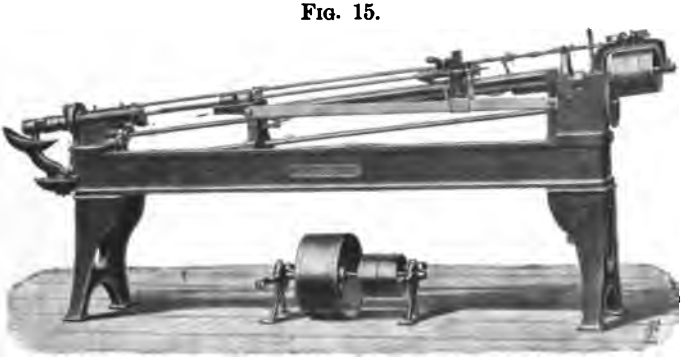
RECENT PROGRESS IN GUNS AND ARMOR.

The Supremacy of Rapid-Fire Guns—Improvements in hardening Armor—The New Dynamite Gun and the Position-Finder.

HUMANITARIANS generally are in hopes that the science of war has developed until it closely resembles the science of peace, which must come to civilized nations when war means utter annihilation. That this period is close at hand is a conviction which forces itself upon the mind after a review of the progress made in offensive weapons since the Civil War. At that date the muzzle-loading rifle, with

the percussion cap, was the principal weapon of the foot-soldier. With this two shots a minute could be fired, and it was possible to inflict harm within a range of half a mile, though it was really difficult to shoot to kill at three hundred yards. To-day the troops of the United States use the Krag-Jörgensen magazine rifle, carrying four cartridges at a loading, and capable of discharging about twenty shots a minute. The bullets are longer, of less calibre, and lighter than formerly, but owing to improved powder have a much greater range and penetration. They will kill at a distance of two miles, which is about as far as a man can comfortably see another without the aid of a glass. They are further dangerous in that the path of the bullet is so nearly a straight line as to sweep all the territory between the firer and the point aimed at, whereas with old-time guns the bullets mostly passed over the

FIG. 15.



RIFLING MACHINE FOR GUN-BARRELS.

heads of intervening soldiers. The best bullets used are made with a hard lead core enveloped in a case of sheet steel that has been plated with nickel-copper. These will penetrate about five feet of pine wood or a foot of hard

sand. William Sellers & Co.'s machine for rifling such guns is here shown.

The Lee rifle, designed by James Paris Lee, of Hartford, Connecticut, has been adopted by the United States navy, and is much like the United States army rifle, though using a bullet of smaller calibre. The former is two hundred and ninety-five thousandths of an inch, the latter two hundred and thirty-six thousandths, which gives a lighter weapon capable of killing at about a mile and a half. The charge is thirty-six grains of rifleite—one of the most powerful of the new smokeless powders. The cartridges are put up in little packages of five, which constitute a load for the magazine. They can be slipped in so rapidly that it is possible to fire eight rounds (forty shots) in one minute. Other nations use equally effective patterns of rifle: the French use the Lebel, the British the Lee-Metford, Austria the Mannlicher, Germany the Hebler, and so on, all these having been introduced within a very few years.

Machine-guns, firing from a series of barrels, have been made to discharge twelve hundred bullets a minute. This has been deemed an unnecessary waste of powder and lead, and the best of them, as the Maxim, now discharge about two hundred and forty to four hundred cartridges a minute. They are arranged to spread the shot so effectively that nothing unprotected can live before their fire.

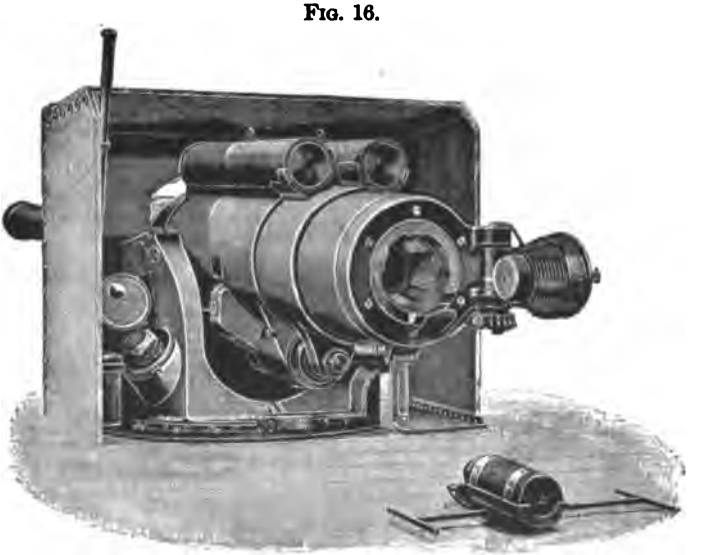
The improvement in large guns has been as marked as in small-arms. The great weapon of assault is now the quick-firing rifled gun of from four to eight inches calibre. At the close of the Civil War we were using quite formidable cannon, the eight-inch Parrott rifle firing a one-hundred-and-fifty-pound shot with a force calculated to carry it through five inches of wrought iron armor, which was

about the heaviest armor employed at that time. Modern six-inch rapid-fire guns are much lighter than the Parrott, as well as more effective. They discharge projectiles of from ninety to one hundred pounds with a force that will penetrate a foot and a half of wrought iron, and, as they can be fired at the remarkable speed of eight or even ten shots a minute, they are the most useful artillery we have. They were introduced about 1886, and have undergone marked improvement since that time. The greatest gain in their efficiency comes from the use of cordite instead of pebble powder. Cordite is so called because it is made in lengths resembling short pieces of cord. It is a mixture of nitro-cellulose and nitro-glycerin, with a little added mineral matter. It is smokeless and possesses fully three times the explosive force of pebble powder.

The Armstrong gun, shown in the illustration, is one of the best guns of this type, being of the design marketed in 1894. It is made in sizes from four to eight inches. It has a protective shield some two inches thick, sheltering the gunners from rifle-bullets. The wheels for training the gun are on the right, out of view. The breech-block, it will be seen, swings on a stout hinge, and may be opened with a single motion. The block is secured in place by what is termed an interrupted screw, having alternate lines of threads and blanks. By this arrangement, instead of having to screw in the breech-block with numerous turns, it may be swung right into place, and tightly fastened with one-tenth of a revolution. The arrangement of the threads in the block is such as to distribute the strain as much as possible The conical shape of the block is considered very advantageous, as allowing it to be directly hinged, whereas, if it were cylindrical in shape, it would have to be withdrawn and then swung open—a loss of one complete mo-

tion. The projectile is loaded from a little hand-barrow, and the shell after firing is removed in the same way—a powerful extractor loosening the shell so that it can be removed from the chamber with a slight pull. This extractor consists of a rod passing through one side of the gun, and fitting into the groove for the rim of the cartridge-case, in

FIG. 16.



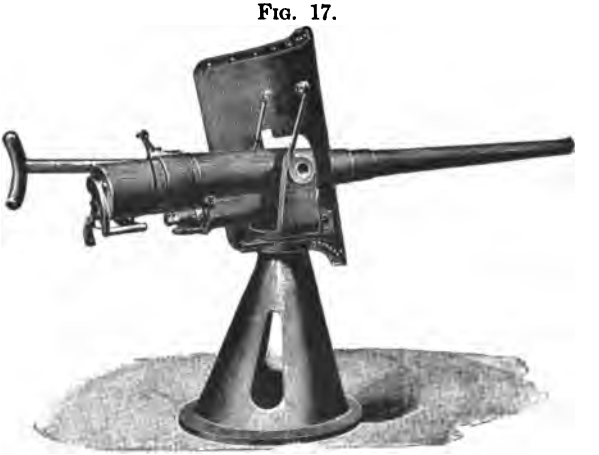
ARMSTRONG GUN.

such a manner that, when it is turned about its own axis, the fitted part acts as a lever or pry, and brings the cartridge to the rear. The extractor is brought back to its place, as the breech is closed, by means of a strong helical spring outside the gun. The gun itself is of wrought iron, the inner tube being of steel, iron-bound.

A somewhat similar gun is the Nordenfelt, which is made in smaller calibres, the one illustrated having a two-

and-a-quarter-inch bore. It is shown with a half-shield, as arranged for naval use, being designed to stand behind a breastwork a yard in height. It is five feet seven inches long, and weighs less than five hundred pounds, yet it fires a six-pound shot with an initial velocity of a quarter of a mile a second, with a fraction over half a pound of smoke-

FIG. 17.



NORDENFELT GUN.

less powder. The same gun is arranged to be mounted on a field-carriage for land service.

Among other modern guns should be mentioned the Canet, adopted in 1891 by Russia, and to some extent by Chili. It has a tube the length of the piece, and is strengthened by a jacket and hoops. A seven-inch gun of this make weighs five and a half tons, and requires five men to operate it. A muzzle velocity of two thousand eight hundred and eighty-seven feet has been obtained with an eighty-pound projectile, and six to eight shots can be fired in a minute.

A very formidable weapon is the Hotchkiss revolving cannon, which fires a nine-inch cartridge, six feet long, and weighing eleven hundred and sixty pounds. The cartridge is filled with shrapnel, and the rate of discharge is ninety rounds a minute, or the equivalent of two thousand two hundred and fifty projectiles. It is mounted on a truck, being designed to protect ditches and fortifications. Only two men are required for its operation.

The largest guns in actual use to-day are of about seventeen-inch calibre, and capable of discharging a two-thousand-five-hundred-pound projectile with a velocity of over two thousand feet per second. They will pierce over forty inches of wrought-iron plate at a short range, or over twenty inches of hardened steel plate. They are about forty times as effective as the two-hundred-pound Parrott gun of the Civil War. About twelve-inch calibre guns are generally preferred as heavy artillery for naval use, since they are lighter and fire projectiles that are equally penetrative. The range of the best of these, under favorable circumstances, is about twelve or thirteen miles.

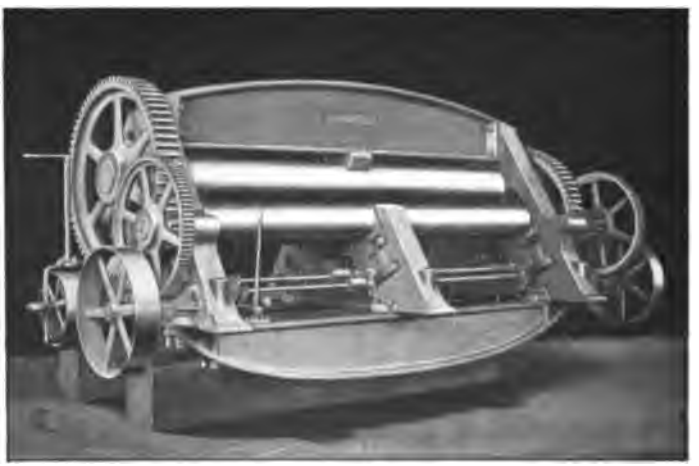
In recent war-ships the guns are mounted in citadels, or turrets, or barbettes. A very heavy belt of armor is placed abreast of the engines and boilers, the thickest point being at the water-line. The remainder of the vessel is only protected sufficiently to guard the crew from fire with small-arms. In what is called the central-citadel system, that part of the water-line abreast the engines and boilers is armored, and a protective deck extends down from the citadel. The unprotected hull is made in compartments, so that it is necessary to blow in at least half a dozen projectiles below the water-line before there can be danger of sinking. The inflow of water at shot-holes is reduced by building the hull with a double skin, the space between the

two skins being filled with cellulose, a material that swells with great rapidity when wet. This cellulose is usually obtained from the husks of cocoanuts, but a Philadelphia inventor has recently succeeded in making a better and cheaper article of cornstalks, and this new cellulose is said to be so efficient that it will greatly reduce the danger of sinking war-ships with rapid-fire guns.

The deflective method of armament is universally practised, and consists in so armoring a vessel that no flat surfaces are presented towards an enemy, the curved surfaces giving the shots a tendency to glance. This is very effective on a deck, because of the large angle obtainable. It is obtained in turrets by giving them a spheroidal shape, and in casemates by convexing the fronts. The turrets for the new United States cruiser "Iowa" are to be made elliptical instead of circular. The disadvantage of the circular turret is that, owing to the position and great weight of the guns, its centre of weight is necessarily nearer the front than the rear. While the ship is standing perfectly level this makes but little difference, but, as the vessel rolls, the turret, with its three to four hundred tons weight, tries to swing alternately in opposite directions with the roll of the ship. In spite of such tendency, it must be forced to move in a direction and at a speed entirely independent of such roll. This requires powerful mechanism and interferes with accurate aim. The elliptical turret, which is twenty-three by thirty feet, rotates about the centre of its weight, instead of its centre of form, so that it can be controlled by a quarter of the power required in the case of a circular turret. What is even better, the accuracy of aim is increased, and the target presented by the front to the enemy is reduced seven feet. It is also possible to make the front plate heavier with the same total weight of metal.

Armor is made of rolled iron, chilled cast iron, forged and tempered steel, and nickel-steel. Compound armor is made of rolled iron and faced with steel. Wrought-iron armor has been made under the steam-hammer and by rolling, the latter process being most common. It has been subject to much experimentation. Chilled cast iron has been largely used in defending European forts. It is

FIG. 18.



SELLERS'S ROLLS FOR BENDING SHIP PLATES.

cheaper than hardened steel, and the increased weight necessary to afford the same protection is an advantage rather than otherwise. Compound plates have been made largely by the Wilson process. This consists in the casting of Bessemer steel in an iron mould, the back of the mould adhering to the cast steel, so that the two become one, and are rolled together to complete the welding. The plate is then bent, shaped, tempered, and annealed to re-

move internal strains. Wilson has also employed a similar process, in which a series of thin iron plates, made by the ordinary process of rolling, are joined in a mould by pouring molten steel between them and subjecting to further rolling and shaping, as in the first-described process. The Ellis system of making compound plates consists in taking an iron and a steel plate, and joining them by putting through or partly through stout pins of about two and a half inches diameter. The plates are then heated quite hot, and molten steel poured in the crack, after which the whole is placed in a powerful hydraulic press and reduced in thickness to complete the union. It is then bent, planed, tempered, and annealed as in the Wilson process.

In making forged steel armor, as is done at the Carnegie works, immense ingots of steel are first cast, and conveyed while still white hot to the one-hundred ton steam-hammer, where they are pounded for a time, then reheated and hammered some more, and so on. A seventy-five-ton ingot requires about nine heatings before it is properly condensed by hammering. It is then ready to be bent and planed into shape, after which it is annealed and the face tempered in oil. Nickel-steel armor is made in the same way, about three and a quarter per cent. of nickel being used in the alloy of which the ingot is cast. This gives the steel slightly more resistance than it has without the nickel.

Harveyizing is a process of surface hardening which has been introduced within a few years to increase the resistance of armor-plates. It is used both for steel and steel-nickel plates, and consists in carbonizing the face in a manner somewhat similar to the cementation process of making steel. This face-hardening grades off towards the interior of the plate, which is not increased in brittleness, as would be the case if the whole thickness were hardened.

The Whitworth armor is made in plates about an inch thick, arranged in scale-fashion, with the hardest plate outside. These are bolted together, and, being made in small pieces, a shot does not damage so large a section as is sometimes the case with large plates, which develop great cracks under severe bombardment. In all systems of manufacture it is customary to bend the plates to form, while hot, in enormous hydraulic presses, or to shape them with the steam-hammer. They are next trimmed up by special planing- and sawing-machines. Large plates are usually fastened to the ship by bolts of two to three inches diameter screwed part way into the plate. One plate of each group made is selected by the government to be tested, by firing into it at short range, and discovering just what it will bear. In a recent important test by the United States government of plates made by several competing firms, a series of ten-and-a-half-inch nickel-steel plates were bombarded with six-inch guns at a distance of only fifty-seven feet from the muzzle. Most of the plates began to crack about the fifth shot, and were severely cracked after fifteen shots.

There exists a difference of opinion as to the value of all steel (or nickel-steel) *versus* compound plates. The Italian government has declared in favor of all steel, the French use both sorts, the United States uses steel, Germany and Russia use compound, while Spain and Chili cling to steel. Since the introduction of Harveyizing the tendency appears to be towards the all-steel plates. The same is true of projectiles. These are commonly made of chilled cast iron, because of its cheapness, but the steel projectiles have considerably more penetration. The heads of projectiles are made in all forms, the flat head being preferable if deflective armor is to be attacked, and

some pointed form if a flat opposing surface is to be battered.

There has existed a long-time struggle between guns and armor for supremacy. At present the armor seems to have the best of it on shore, and the guns at sea. In recent wars vessels have been very shy of approaching land-batteries. Even as far back as the Franco-Prussian War, though each nation possessed an efficient fleet, no attempts were made to assault each other's harbors. In contests between naval vessels it has been demonstrated that accurate fire will damage a vessel to the point of annihilation. Battle-ships are by no means invulnerable, and a reaction exists in favor of light-armored cruisers that can win by their speed more than they lose by not loading themselves with a heavy armament. If they encounter a vessel with guns of greater range than their own they can run away. So the value of the heaviest battle-ships is nullified, since they cannot fight shore-batteries on even terms and light cruisers will not lie around to be whipped. If this opinion is correct, Great Britain is destined to lose something of her supremacy, for her vast navy is largely made up of vessels of the heavy class. The present year ten first-class battle-ships are being added to the queen's navy, the largest one costing nine hundred and eighty-three thousand pounds, which shows that the British are not yet convinced that the day of floating batteries has gone by. The demand for fast cruisers is also recognized, however, and ten of them are under contract, with guaranteed speeds of eighteen and nineteen knots. Twenty torpedo-boat destroyers are also to be built, and the rumor is that they are each to have a speed of thirty knots an hour.

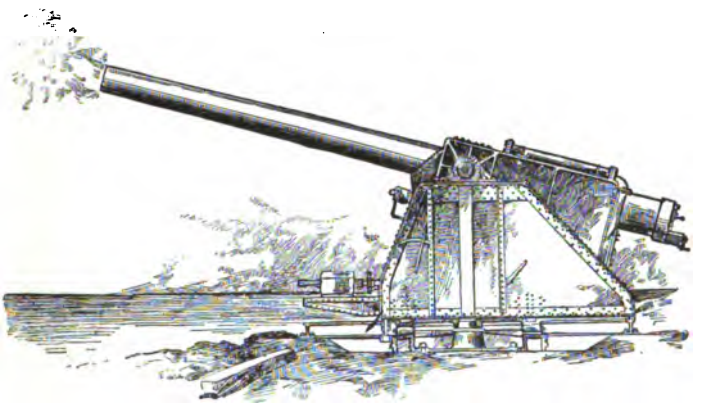
Meantime, Uncle Sam, who does not aim to rule the seas, but simply to be safe at home, is perfecting a system

of harbor defence that would seem to be impregnable. At the entrance to New York bay, on Sandy Hook, are earthworks, shielding disappearing guns, and others are projected on Coney Island and vicinity. Across Romer Shoal it is proposed to erect four steel turrets, set on steel piling in the most substantial manner, and protected from the corroding action of the water by masonry. The magazines, machinery, and quarters for the men will be located under water, safe behind a bank of sand. The turrets will be circular and revolving, and, being on land, they can be protected with any desired thickness of steel plates that is thought necessary. Each turret will carry two guns of the largest calibre, and a number of rapid-fire six-inch and eight-inch guns will also be provided. The situation of these turrets is such that the guns will sweep all approaches to New York, and it is not thought that any hostile fleet would ever undertake to come within their range in daylight, as the aim from a land-battery is much surer than from a vessel, and the fleet would stand little chance of getting away uninjured. The battery at Sandy Hook is provided with ten- and twelve-inch steel rifles, a number of twelve-inch steel mortars, and some pneumatic dynamite guns. The proposed batteries at Coney Island and along the Jamaica shore will no doubt be similarly or better armed. All these weapons will be under or back of bomb-proof shelters, and will pop up to send their deadly missiles and disappear before an enemy can train a gun on the spot.

Recent inventions render it a matter of doubt whether there is such a thing as a bomb-proof shelter, for the latest improvement in dynamite guns seems capable of blowing up any structure of man's manufacture. The original dynamite gun, invented by Lieutenant Zalinski, is more

properly called the pneumatic gun, since it makes use of compressed air to discharge the projectile of explosive material. It consists essentially of a tube, forty to sixty feet long, not very heavily made, and supported by a truss to insure it against warping out of a true line because of its weight. Below its carriage is a chamber for compressed air, which is stored at a pressure of four thousand pounds, and used at an effective pressure of two thousand pounds.

FIG. 19.



THE NEW DYNAMITE GUN.

The most difficult part of the invention was the construction of proper valves for admitting the compressed air with such rapidity that the pressure could be increased as the projectile came near the end of the long tube. By using a low pressure at the start and increasing it as the projectile left the tube it was possible to get more force, and to send the projectile a greater distance than could be done in any other way. It is impossible to use great initial pressure on a projectile containing dynamite or other high explosive, because the shock will explode the projectile in

the gun, whereas the object sought is to have it explode where it falls, after being hurled with all the cushioned force that it is safe to use. The range of the pneumatic gun is about two and a half miles, and the public has been informed that this could probably be increased to four or five miles; but as there are rifled guns that could stand off at a distance of ten miles and knock the pneumatic dynamite gun to pieces, its value as a military weapon has been subject to much discount. It is at this point that the recent improvement comes in. Hudson Maxim, brother of Hiram S. Maxim, inventor of the flying-machine that flew, and Dr. Schupphaus, the gunpowder expert, have been putting their heads together, with the result that within a few months they have taken out patents in all civilized countries on what they call "the Maxim-Schupphaus system of throwing aërial torpedoes from guns by means of a special powder, which starts the projectile with a low pressure and increases its velocity by keeping the pressures well up throughout the whole length of the gun." In other words, they have discovered a method of discharging a dynamite projectile with a powder gun instead of a pneumatic gun. They are able to do this because they have devised a powder that will give out its gas gradually, if we may apply the word to a process that takes place within an infinitely small fraction of a second. It should be understood that high explosives for cannon are now put up, not in the form of powder, but of cylindrical rods or sticks, sometimes half an inch or more in thickness, usually tied up in a bundle. The Maxim-Schupphaus invention consists in manufacturing these explosive sticks with small holes, that perforate them lengthwise, and are capable of giving out the gases at the forward end while the whole is burning. In practice the

rods are ignited simultaneously at both ends, along their outer circumference, and through these little holes or perforations, so that by the time the projectile has reached the end of the long tube the pressure behind it is sixteen times as great as it was at the starting-point. This acceleration of speed makes it possible to start with an initial shock so mild that a highly explosive projectile may be fired instead of a steel shot, with a possibility of destruction that is terrible to contemplate. The effective range is said to be ten miles, or almost equal to that of guns firing the solid shot. When one of these torpedo projectiles from the new gun strikes an object it will not simply shatter it, but obliterate it from the face of the earth—or the sea. The inventors make use of an explosive that has been christened Maximite, which owes its force principally to nitro-glycerin, but has been rendered safer to handle, in order that it may withstand the first shock of firing in the new gun. As a matter of fact, this new gun is not yet finished, but it is an assured success, since the principle has been tried with smaller guns. One of the Sandy Hook ten-inch rifled guns fired a shot eight miles with the new powder, which exhibited what the experts term a more uniform pressure than any before recorded, with the result of securing greater accuracy of aim, or rather delivery. The inventors have fired their explosive projectile from a four-inch gun, with the result of annihilating a sand-bank. The big weapon they are now building is to be a twenty-inch gun, especially designed for coast-defence. It has a single steel tube thirty feet long, with walls only two inches thick, so that it will be a light weight, like the pneumatic gun. The recoil is to be taken up by buffers sinking back into an hydraulic chamber filled with water and oil. When the gun is fired, some of the water and oil will be displaced

and forced into side chambers. These side chambers are thus charged with a power that may be used to manipulate the gun, as for erecting it on disappearing-levers. The gun is so light and simple in its construction that it will be much cheaper to build than any other large gun.

If a few of these guns are placed at Romer Shoals, no hostile vessel would dare to approach within range, for if one of the projectiles dropped within fifty feet of the biggest battle-ship it would shatter and sink the whole structure. Even at a distance of a hundred and fifty feet the shock of explosion would be so great when the Maximite struck the adjacent water that the heaviest steel-clad boat would be rendered unfit for further service. A naval battle under such circumstances would become a grand chasing act, the hostile fleets endeavoring to deliver a shot that would reach and to get away before being hit in return.

The gunners who would defend a harbor with the latest improved mechanisms would be entirely ignorant at the time of what they shot at, whether they hit anything, or what were the circumstances of the battle. They would simply take their orders from the man with the position-finder, and blaze away blindly. This position-finder is the invention of Lieutenant Bradley A. Fiske, and is an apparatus designed to locate exactly the position and distance of any object within range and convey the information electrically to the gunners, so that the pieces may be directed continuously and automatically on a moving object, as an enemy's ship. The position-finder will convey the information to as many guns as are connected with it, and by using several position-finders different groups of guns may be brought to bear on one point, and other groups on other points, as desired. The plan is to establish a directing station on some high point, from which

there is an unobstructed view, and which is far enough back to be out of range. Here are stationed operators, with two telescopes and a chart of the harbor, over which are electrical pointers made to vary according to the pointing of the telescopes. Similar pointers beside the guns are electrically connected on the principle of the Wheatstone bridge, with the result that the guns may be kept constantly pointed at the object upon which the telescopes are trained. The apparatus is too complicated and technical to allow of a popular description, but suffice it to say that the guns themselves may be used as pointers at the receiving station, and that the man in charge of the training (or side-motion) of the gun has simply to watch one galvanometer, while the man in charge of the elevation of the gun watches another, and by keeping the needles of their galvanometers at zero the gun is sure to be aimed as accurately as are the telescopes, and may follow a moving ship, while loading is going on, so as to be exactly pointed at the instant of discharge. This method of firing has been tested at the Sandy Hook batteries, with the result that ten consecutive shots all fell within a space one hundred and ninety-five and one-third yards long and eight and a half yards wide, or about the space occupied by a large ocean steamer. Of course nothing that floats could withstand such an assault. Shore-batteries armed with the new Maxim-Schupphaus guns, and sunk behind sand-bars where they were out of sight, would blow a hostile fleet similarly armed out of the water before the artillerymen of the fleet had learned where the batteries were to fire at them.

The inevitable result of all these remarkably destructive appliances must be the cessation of wars between civilized nations. In fact, war is not a civilized thing. It is a relic of barbarism that the world is just beginning to out-

grow. After providing themselves for a few hundred years with expensive and deadly armaments that involve destruction to whoever opposes them, the enlightened nations of the world will some day agree to allow the whole lot to go to decay under mutual agreement for endless peace.

SUBMARINE BOATS.

Naval Authorities of the World mostly interested in or experimenting with Electric Boats designed to carry Torpedoes beneath the Waves.

EVER since the days of Jules Verne's "Twenty Thousand Leagues under the Sea" there have been many who wished to see a real boat capable of navigating below the surface and examining the wonders of the deep after the fashion of Captain Nemo, who sailed the fabled "Nautilus." The romantic enterprise of such a journey, akin to searching for the North Pole, and involving experiences never before tried by men, creates an interest which is more or less common to all. Novelty is agreeable to most of us, and the desire for novelty has in the past encouraged many men to try to navigate the air, and there is no good reason why they should not also strive to explore the depths of the waters. Only within a very few years has the latter seemed at all possible, but recent attempts at submarine travel indicate that these air-tight boats may one day be able to reach depths which are now known only through the medium of the sounding-line.

It is to torpedo warfare that we owe the progress made in submarine boats. Naval powers desire boats that will steal unawares upon the big battle-ships of an enemy, and

deliver the deadly explosives where they will accomplish the most certain destruction, themselves remaining unseen. In 1888 this sentiment culminated in several attempts to construct boats for this subaqueous warfare. Lieutenant Peral, of the Spanish navy, designed one of seventy-two feet length, nine and a half feet beam, and a displacement of eighty-six tons. Her form was cigar-shaped, which is a construction that has been universally adopted, perhaps without wholly good reason, as has been demonstrated in the case of aërial ships. This boat was called the "Peral," and was operated entirely by electricity, carrying six hundred and thirteen Julien cells as a storage-battery. She was designed for a speed of ten or eleven knots. Twin propellers were used, each separately driven by its own motor. The two other propeller-screws were used to draw the vessel downward in the water and secure the required submersion. There were large water compartments, which could be filled or emptied by pumping, for the purpose of raising or lowering the vessel, or assisting those operations. The double method of securing buoyancy served as a safeguard against accident. A most ingenious mechanism was adopted for regulating the depth of travel below the surface. It operated on the principle of an aneroid barometer, the change in pressure resulting from a change of depth being made use of to regulate the action of the immersion-screws. A curved tube of elliptical cross-section was extended from the boat into the water, so that it might be deformed by changes in pressure, such deformation operating a switch to set the immersion-screws revolving so as to raise or lower the craft as the case required. A contact-pendulum operated somewhat similarly to keep the stem and stern at corresponding elevations. If the stem sank a trifle the pendulum swung against the forward contact, establish-

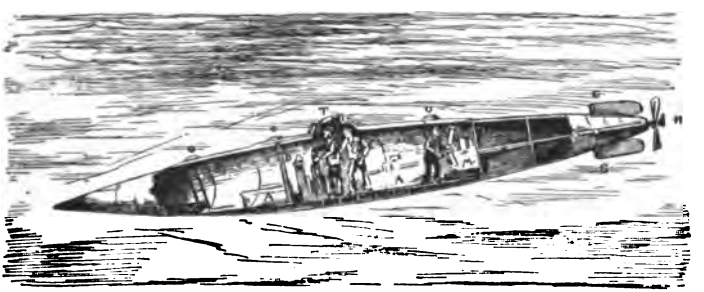
ing a current of electricity that adjusted the screws so that the boat was righted.

The first practical attempt in England was made in the same year (1888) by J. F. Waddington. His boat is smaller than the "Peral," being designed to be carried on the davits of a large naval vessel for use in emergencies. The length is thirty-seven feet, and the circular section amidships six feet in diameter. A little tower on top enables the steersman to look around when skimming just below the surface. There are two compressed-air compartments designed to refresh the air when requisite, and provision is made to allow the foul air to escape whenever the pressure is greater inside than outside. The electrical motor develops eight electrical horse-power and drives the propeller at a speed of seven hundred and fifty revolutions per minute. Forty-five large accumulator-cells are used, and the speed developed is about twelve miles an hour, while at a slow speed a travel of one hundred and fifty miles can be made before it is necessary to recharge the batteries. Water-tanks are used, into which a flow is admitted to sink the vessel, and pumped out again to assist its rise. A weight is also hung to the bottom, so that it may be detached in case of accidental difficulty in reaching the surface. Side planes are made use of to guide the vessel on an upward or downward inclination, assisted by the force of the propeller-screw. There are also vertical propellers, mounted in large tubes passing vertically through the vessel, which may be used to assist the raising or depression of the craft. Four rudders are employed—one pair serving to guide the boat laterally and the other pair vertically. The latter operate automatically. The crew consists of only two men—one to manage the motive machinery and steering devices, the other to fire the tor-

pedoes, of which there are two of the automobile type and one of the mine type. The trials of this vessel are said to have been very satisfactory.

France came forward the same year as Spain and England with an electrical submarine boat designed by M. Gustave Zédé, of the Mediterranean Engineer Corps, with the assistance and advice of Captain Krebbs and Engineer Romazzotti. Strange to say, though all three of the vessels described were built in a single year in different countries, by men who could scarcely have had any communication with each other, yet the general principles of these boats are the same. The illustration shows the "Gymnote,"

FIG. 20.



THE "GYMNOTE."

as M. Zédé's craft is named, in the act of diving. She is fifty-nine feet long, six feet in diameter, and has an outer skin made of riveted steel plates two and a half by three feet in size. The propeller H has four blades, and a diameter of four feet ten inches, and is directly connected with the motor M. An outlook for the steersman is provided at T, and he operates the steering-gear connecting with the rudders G, G. The accumulators, weighing nearly six tons, are stored at A, A. Man-holes are shown at O, O, O.

The motor, as well as the rest of the electrical arrangements, was designed by Captain Krebbs, and develops fifty-five horse-power, with a weight of only four thousand four hundred pounds. Horizontal rudders or guides, assisted by the power of the screw, are used to submerge the boat. Hydraulic power is used for their operation. The speed is ten knots an hour at the surface, or five to six knots at a depth of eight yards, which is as deep as she is designed to go. Incandescent electric lights are used for illumination. There are water-chambers and compressed-air chambers, as in the previously-described vessels. Though an experimental boat, the "Gymnote" is declared to be a complete success, and the French government has appropriated about two hundred and twenty-five thousand dollars for a larger vessel of the same design, properly armored with torpedoes. The "Gymnote" has been publicly tried on several occasions, and has always behaved satisfactorily, diving and manœuvring entirely as desired.

The French government has also built two small submarine boats—the "Gouber," eighteen feet long, and a torpedo-mine destroyer fifteen feet in length. Each is designed to carry two men, and the former carries an air-supply capable of supplying the crew for a period of thirty-three hours, which would appear to be ample for any submarine work.

Russia has also built some submarine boats, but, with her usual caution, that power declines to publish any information concerning them.

A firm at Foce, Italy, have built a steel submarine boat for examining the bottom of the Mediterranean in search for treasure, and probably also for the amusement of those concerned. She is twenty-eight feet long, seven feet beam, and eleven and a half feet high at the centre—a form not

common to other designs. Electricity is the motive-power, and a screw-propeller utilizes the same. She is so arranged in compartments that divers can crawl out of her, when resting on the bottom three hundred feet below the surface, and examine wrecks, chase for pearl oysters, etc. None of the other boats have attained any such depth as this little vessel, which seems to come nearer realizing the dream of Jules Verne than any of the torpedo-boats.

The best-known submarine boat which has been constructed in the United States is that built by George C. Baker, of Chicago, which was tried on Lake Michigan in May, 1892, and at a later date. This boat, which has been often described in the newspapers, is radically different from the foreign craft of the same class. The shell is made of oak six inches thick, to form which planks of proper curve, three inches thick, were spiked together with their edges outward. She is forty feet long, eight feet beam, and thirteen feet high. She makes use of storage-battery cells, an electric motor that may serve as a dynamo, and a steam-engine. In practice, the design is to come to the surface, get up steam, charge the batteries by means of the dynamo, and, when sufficient power is thus stored, put out the fires, use the dynamo as a motor, and speed away beneath the blue waves. The smoke stack is protruded through a valve or withdrawn at pleasure. There is a little observation-tower for the pilot's head, its sides being fitted with plate-glass panes. This conning-tower also serves as a cover for the manhole. Two propeller-screws, each four-bladed and two feet in diameter, are arranged to be driven at adjustable angles, so that the pilot can direct the boat to right or left, or up or down, by a proper adjustment. The dynamo-motor used is of fifty horse-power capacity, and is connected with two hundred and thirty-two Woodward

storage-cells. The pressure used does not exceed two hundred volts. The shaft makes nine hundred revolutions a minute, which gives a speed of about nine miles an hour. Two men constitute a crew, and they have to manage the steering apparatus that controls the rudder and the wheel that alters the angle of the propellers. The trials of this boat have been satisfactory as a whole, though minor details have been noted that might be improved. She has attracted the attention of the United States navy as a practical torpedo-boat, but as yet this government has taken no steps to secure her. A few years ago the navy advertised for a submarine boat, but demanded so much of her that no one undertook to supply the demand. Among the requirements was a speed of fifteen knots for a period of thirty hours, without detriment to her power of service under water.

A submarine boat named the "Nautilus" was tried in New York harbor a few years since, but was not entirely satisfactory. By the advice of the late Andrew Campbell, the well-known maker of printing-presses, her buoyancy apparatus was changed and four extensile cylinders placed in her sides in such a manner that by thrusting them outward the air-space was increased and the boat rose, or by withdrawing them the boat could be sunk. It would appear that this principle might be advantageously employed in making a boat designed to explore the ocean depths. If the boat itself were made telescopic, a vast variation of buoyancy could be secured, and if to this were added the use of inclined wings driving the boat downward by the force of her propeller, and also a detachable weight supplied to be thrown off when it was desired to rise, it might be possible to attain a depth of several hundred feet, and by the aid of powerful search-lights learn more of the unknown regions hid beneath the waters of the ocean.

Inventors, having built principally for torpedo service, have neglected this interesting branch of research. Since no great speed is required of a boat designed primarily for diving, the form might be changed from the cylindrical to triangular, which would save something in the cost of construction. By placing one flat side of the triangle upward an effect similar to that of aëroplanes might be obtained to aid in driving downward. A boat so designed might be very useful in inspecting ocean cables, examining wrecks, etc. The idea is so attractive that some day some one will furnish the money to carry it out.

FLYING MACHINES.

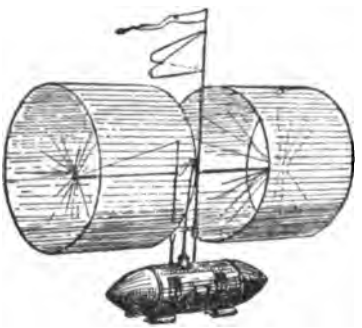
Navigation of the Air by means of Aeroplanes—Successful Experiments of Hiram S. Maxim.

MACHINES that would fly have been the ambition of many inventors, but never could one of them be pulled off the ground without a gas-bag until July 31, 1894, when Hiram S. Maxim, inventor of the Maxim gun, turned loose his aëroplane flyer in England, and skimmed over some five hundred feet. For several years past the attention of scientific men has been turned from the balloon, as a means of aërial navigation, towards forms of inclined planes that could be propelled through the air and lift themselves after the manner of a boy's kite. Professor Langley, of the Smithsonian Institution, as well as Mr. Maxim, had demonstrated by experiments that at a speed of thirty-five miles an hour the lifting power of air was

sufficient to sustain a light form of apparatus carrying a motor, fuel, and operator.

Several experimenters worked on these lines, 1893 being the year prolific of promising devices. Among these inventors was Professor George Wellner, of Brunn, Austria, who exhibited designs of an air-ship of the novel form shown in the illustration. There are interior sail-wheels, for which he obtained a patent in England in May, 1893. He gave these wheels an oscillating, rotary motion, which he expected to sustain the machine in the air at the same time that it was driven forward. No one has been found to furnish the money to build one; therefore its feasibility remains in doubt.

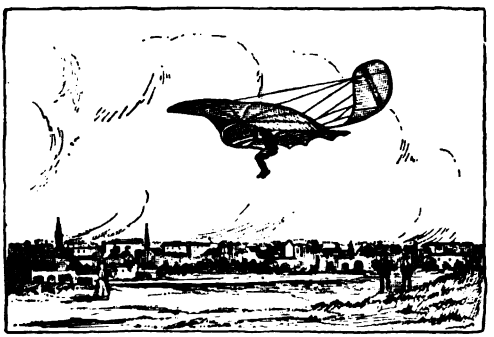
FIG. 21.



PROFESSOR WELLNER'S AIR-SHIP.

In the same year, Otto Lilienthal, as the result of some years' experimenting, built a wing-like framework, and practised soaring in the vicinity of Berlin, in the hope of being able to maintain himself in the air as do the birds. His wings were fifteen metres in area, and his method was to take a run against the wind, from a roof-top situated on a hill, and jump into the air. In this manner he was able to soar a distance of about eight hundred feet on a down grade before reaching the ground. His experience was so unique that it would not be surprising if it were tried by others as a sport, though no man can ever expect to develop enough strength to fly in this way.

FIG. 22.



LILIENTHAL'S SOARING APPARATUS.

Lawrence Hargrave, of England, built this same year a singularly light machine designed to imitate the flight of a bird. It was seven feet long, and consisted of a tube or backbone on which were mounted a pair of wings, yet the weight was only fifty-nine ounces. The backbone being charged with compressed air, this mechanical bird flew away, covering a distance of three hundred and fifty feet before falling. His design was much like that of a Mr. Pichancourt, who had previously made smaller mechanical birds, using twisted rubber as a motive power. These birds flew sixty-three feet. Mr. Hargrave's experiments led to the conclusion that by using steam in the backbone of his bird it could be made to fly over five hundred yards. Mr. Hargrave has also built a seven-pound steam-engine that developed two-thirds of a horse-power.

Between 1890 and 1893, Horatio Phillips, of England, made extensive experiments with a rotary track, such as Maxim and Langley used in their experiments, but his track was the largest and his apparatus the most complete of the three. He has common-sense theories, and it would

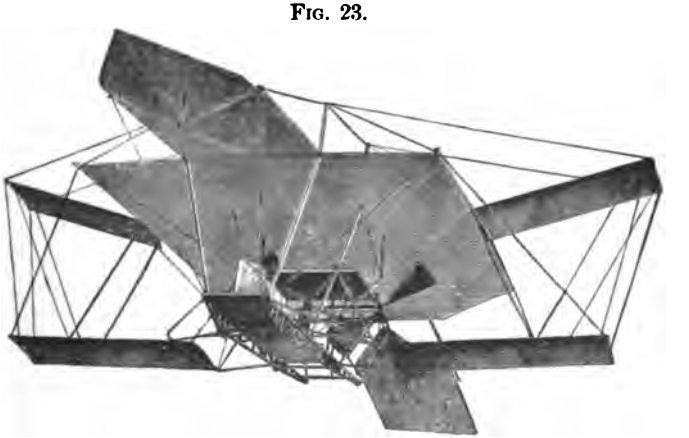
not surprise those who have observed his operations if he also made a machine that would actually fly. His machine weighed three hundred and thirty pounds, its aëroplanes being arranged like the slats of a Venetian blind. The slats were twenty-two inches wide, with a cross-section shaped like the curve of an albatross's wing. The propeller was six feet in diameter, with eight feet pitch. It was designed to make four hundred revolutions a minute. His boiler was of phosphor-bronze, twelve by sixteen inches, and contained three-quarter-inch tubes.

Professor Langley's aluminum aëroplane is like a great bird, measuring ten feet from tip to tip of the wings. The latter incline upward, and the air-ship is sustained much like a kite, except that, instead of depending on the wind, there are two small screw-propellers. A light steam-engine furnishes the motive power. It was recently tested at Quantico, Maryland; but the aëroplane was eccentric in its motions, and requires further experimentation to perfect the machine.

As early as 1856, Mr. Maxim's father had the idea of a flying machine, but at that date no suitable motor could be obtained to drive the propellers. In 1858, Peter Cooper, working on independent lines, undertook to make a motor for a like purpose, exploding chloride of nitrogen in a cylinder, but, receiving a severe hurt in the eye from a little explosion, he concluded that it was best to stop while his head remained on his shoulders. Cooper's idea, and also Maxim's at that time, was to lift the machine by a propeller turning on a vertical shaft and thrusting downward. At first thought this seems the only feasible way, yet the problem was solved by making propellers that thrust backward like those of ocean steamers, inclined planes, called aëroplanes, being used to sustain the weight.

Maxim's experiments were made in a large field, where he laid a railway track, his idea being to run the machine along the track until it acquired a speed of about thirty-five miles an hour, when it ought to leave the track and soar upward. He met with a great deal of difficulty in securing a motor sufficiently light. The oil-engine seemed suitable because of the light weight of the fuel, but he was unable to build one light enough to come within the necessary limits. Next he tried an engine using naphtha as steam is

FIG. 23.



MAXIM'S FLYING MACHINE.

used. Naphtha vaporizes at such a low temperature that this seemed likely to succeed. It was a mechanical success, but the extreme danger, resulting from the great inflammability of the vapor, caused its abandonment. At last Mr. Maxim came back to the steam-engine, and sought to devise one that might meet his wants. Here the great difficulty was with the boiler. He must avoid carrying a great steel shell with a large body of water. He finally succeeded in building a boiler having thin

copper water-tubes, through which a forced circulation of water was kept up, and secured eight hundred feet of heating surface with only thirty feet of flame surface. His fuel is gasoline, and, although the boiler makes more steam than the three hundred and sixty-four horse-power engines consume, yet it weighs but twelve hundred pounds, including the two hundred pounds of water it requires. The gasoline fuel is blown in a generator, weighing one hundred pounds, at a pressure of fifty pounds, making a flame twenty-two inches high.

The double-expansion engines weigh six hundred pounds, or a little less than two pounds to the horse-power, a result never attained before, if we except Laval's steam turbine. They are designed to use steam at a pressure of over three hundred pounds. The piston-speed is seven hundred and fifty feet per minute, and the stroke one foot. These engines are made throughout of high-grade steel, many of the parts being tempered to give them greater strength. Some may wonder why aluminum was not used, since that metal is so very light and no longer of serious cost. The reason is that, weight for weight, a high grade of steel is two to three times as stout as aluminum, the popular impression to the contrary being erroneous.

The screw-propellers are of seventeen feet six inches diameter, and have sixteen feet pitch. Mr. Maxim is now satisfied that they should be longer. The propellers are mounted side by side, and the steering is effected by slightly reducing the speed of the engine and its propeller on the side towards which it is desired to turn.

The next difficulties to be overcome were in the construction of suitable aëroplanes. Experiments satisfied Mr. Maxim that they should be superposed, and set at considerable elevations, so as not to interfere with each

other's supply of air. The arrangement finally decided on is best shown by the illustration, but it does not show their construction. Each aëroplane consists of two thicknesses of balloon cloth, stretched on a tubular framework. The lower sheet is slightly porous, allowing some air to pass through against the upper sheet, which is air-tight, and which in operation becomes corrugated into billow-like vibrations. This arrangement was found necessary because the lower sheet must be kept flat, to be of proper service as a lifting plane. When made in one thickness the sheet would bag and flap, but the doubling of the sheet allows all the flapping to go into the top sheet, where it is of little disadvantage. This arrangement is found to be nearly as efficient as if made of solid wood, and of course is of less weight. These aëroplanes were placed at an angle of one foot in eight, and the whole framework was well braced with tubes and wires of the toughest steel. A gyroscopic wheel was depended upon to keep the machine running in the same plane. The total area of lifting surface was four thousand square feet, the width of the machine being one hundred and four feet, and the length one hundred and twenty-five feet. The weight of the apparatus, with three men, is about eight thousand pounds, and its lifting capacity ten thousand pounds.

The great credit due Mr. Maxim for his success is emphasized when we consider how many things he had to invent to accomplish his purpose. He had to make a boiler and engines lighter than any had ever been made before. He had to invent aëroplanes that would not flap, and he had to design an arrangement of the whole combination that would come within the very limited restrictions of weight, to go beyond which insured failure. He did all these things, and he promises to do even better in the future.

On the memorable day when this machine was tried—July 31, 1894—it was run over the seventeen hundred feet of track to see how much lifting power it would exert on the upper rails, for the careful inventor had arranged both upper and lower rails, so that when the machine was raised off the ground it might not fly away and get lost.

Fig. 24.

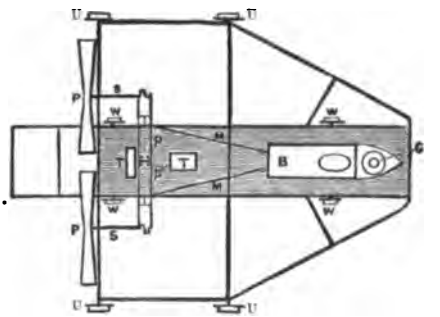


Diagram of Maxim's Machine.—P, P, propellers; S, S, shafts; p, p, pumps; T, T, tanks; M, M, pipes; B, boiler; G, gasoline boiler, W, W, W, W, wheels for lower track; U, U, U, U, wheels for upper rail.

On the third trip the flying machine left the lower track after running four hundred and fifty feet, with the steam at two hundred and seventy-five pounds, when it began to oscillate against the upper rails. At a distance of six hundred feet it rode entirely against the upper rails, the steam-pressure being then three hundred and ten pounds. When about one thousand feet were covered the lifting pressure became so great that the rear rail-wheels were bent out of position and tore up the track, consisting of three-by-nine-inch timber rails, for a distance of about one hundred feet, resulting in the wrecking of the machine. Maxim had a dynograph attached, for recording the amount of lift at various distances run and the amount of steam-pressure at

the time. The two previous runs over the track gave him actual experience as to the lifting power of his aëroplanes under different circumstances. On a run of seventeen hundred feet, with one hundred and fifty pounds of steam, a lift of two thousand five hundred pounds was exerted during a little over five hundred feet of travel. With two hundred and forty pounds of steam, in a run of seventeen hundred feet, the two-thousand-five-hundred-pound lifting point was passed after making only three hundred and fifty feet of run, and four thousand five hundred pounds lift was attained after running nine hundred feet, and maintained for fully six hundred feet. On the last run, when the steam went up to three hundred and ten pounds, the dynograph recorded an amazing rise, the lifting power at each one hundred feet of that trip increasing as follows: 700, 1700, 3000, 3700, 3950, 5750, 6600, 6450, 6500, 8700. From this record it is easy to see that a steam-pressure of three hundred and fifty pounds would have given a speed, in a run of one thousand feet, sufficient to cause a lifting effort of ten thousand pounds. When we reflect how little headway a railway train can make in a thousand feet, this result is little short of marvellous. As Mr. Maxim's engines and boiler are capable of being run at four hundred pounds pressure, even more astonishing results may be expected. Since nobody was hurt in the final break-down, and as the machine has demonstrated that it can fly, the achievement has passed into history as most remarkable, and the public await with interest the next attempt of this now famous inventor. He has built a machine that can lift itself clear of the ground, with two thousand pounds pull to spare. Will he be able to guide it safely through the air and alight without danger? These are difficult problems, yet not so difficult as those which he has already

overcome. His next machine will have the advantage of propellers twenty-two feet in diameter, engines of larger stroke, and aëroplanes set at a less angle. In other respects the design of the wrecked machine will be followed.

Mr. Maxim is of the opinion that flying machines will never be of much utility except in war. As freight-carriers he does not think that they will ever compete with surface lines. Probably he is correct. Yet the general introduction of flying machines would be no greater marvel in these days of progress than was the locomotive a few years ago. Nobody expected such a development of railroad travel as followed, and while nobody of to-day looks for aërial travel to become as common as railroading, it is among the possibilties of the future.

HORSELESS VEHICLES.

Electric and Gasoline Carriages and Bicycles coming into Use, and likely to bring about the Disuse of the Horse for driving.

THE horse is doomed. The noble animal has withstood the inroads of the steam-railways, and seen the bicycle and the trolley usurp fields of usefulness in which he once reigned supreme, but he cannot remain in the face of the automobile carriage for pleasure and business purposes, and his sphere henceforth will be purely that of a trotter, reared for speed and sport, but not for usefulness. Such is the conclusion arrived at after a study of the progress made in this form of vehicles, and a knowledge that manufacturers are already in the field prepared to flood the country with all sorts and shapes and sizes of horseless

vehicles. The only drawback at present to their general use is the lack of good roads, but the public everywhere is awake to the necessity of bettering the roads, and within a few years the United States will make as good a showing in this respect as any of the old countries of the globe. The bicycle is so universally used by young and old that all have learned more or less of the desirability and necessity of good roads for wheeling, and such roads are coming as fast as they can be built.

The bicycle has done another thing towards opening the way for automobile carriages. It has taught mechanics how to construct vehicles of great strength and extreme lightness, and how to make them easy-riding. When horses did all the pulling, men did not care much whether the animal had to exert his strength to draw a hundred or two pounds extra because a vehicle was not made as frictionless as it might be. But just as soon as men and women came to furnish the propelling power, they found out that a multitude of minor devices could be introduced to lighten the labor and increase the speed. So we now have pneumatic tires, ball-bearings, and tempered tubular steel frames, to lessen the work and increase the pleasure of the rider. It is just these things that are desirable in a carriage propelled by a small self-contained motor, and which make it possible to build them of moderate weight and with fairly large carrying capacity.

As long ago as 1889 a good road-vehicle propelled by steam was in use in France. M. Serpollet, the inventor of a steam-tricycle, and M. Archdeacon, an aëronaut, made a trip in one from Paris to Lyons in that year, nine days being spent *en route*. As they met with some accidents, and stopped in all the large towns, this must not be taken as a measure of the speed attained.

One firm of American bicycle manufacturers is now arranging to put on the market a bicycle carriage arranged to be propelled by two sets of treadles and to carry passengers. No doubt it will have a sale, though the greatest success is anticipated for those vehicles that carry a motive power, as an electric accumulator or gasoline engine. Mr. Thomas C. Martin, a New York electrical engineer, expects to see such vehicles hitch on to the trolley in the near future. He says, in a recent interview with a writer for *Munsey's Magazine:*

"It is not impossible that in the near future we shall have power-wires strung along our roads, to which any one can hitch his electric carriage, to drive it in either direction for business or pleasure. To facilitate this there should be switches and turnouts, of course. If the 'two-decker' streets, which all our big cities must eventually adopt, are established, the power-wires for electrical carriages and carts will probably be relegated beneath the surface roads. How soon may this system be established? Already all the new buildings go down three or four stories below the normal street level; and there seems to be no good reason why traffic should not be stratified in the same manner, with the help of electric power. Electricity, or, for that matter, any agency that will drive the horse from the streets of our great cities, should be welcomed, for horses are the cause of much disease and unsanitary conditions. There are laws preventing citizens from keeping certain domestic animals within the city limits. I believe the advance in electricity will soon add the horse to the prohibited list, along with pigs and cows."

The opinion is not by any means extravagant. It is the deliberate judgment of a man who has given a great deal of attention to the future progress of electricity and me-

chanics generally. Engineers will endorse the view, though opinions will differ as to the motive powers likely to be employed. In a machine which is made in Springfield, Massachusetts, a gasoline engine is used, hid away under the seat. This engine is an admirable one, and constitutes the valuable feature of this invention. It only weighs one hundred and twenty pounds, although it has double cylinders. The gasoline used is vaporized, a few drops at a time, and ignited by an electric spark, causing a sudden expansion (in the nature of an explosion under control) that drives the piston, after the manner of a gas-engine. Forty cents' worth of gasoline is claimed by the makers as sufficient to carry the vehicle one hundred and fifty miles over good roads with a light load. The gearing is regulated for speeds of three, six, ten, and (it is claimed) sixteen miles an hour. This gearing is of the type used in trolley-cars to lessen noise, being made of alternate layers of rawhide and iron plates. Ball-bearings are used throughout, and the wheels are rubber-tired, or pneumatic tires can be added at an extra cost. The forward wheels do not turn in connection with the axle, as do those of most vehicles, but are pivoted in the hub, and turned by connecting-levers controlled by the driver. Side-movement of the driver's lever guides the carriage to the right or left, and starting, stopping, or reversing or altering the speed are all accomplished by vertical movements of the lever. A thumb-button operates a brake powerful enough to stop the carriage within a few feet, and another button serves to put the carriage at its utmost speed, as for racing. The total weight of the vehicle is six hundred pounds, about that of an ordinary pleasure carriage of the same capacity.

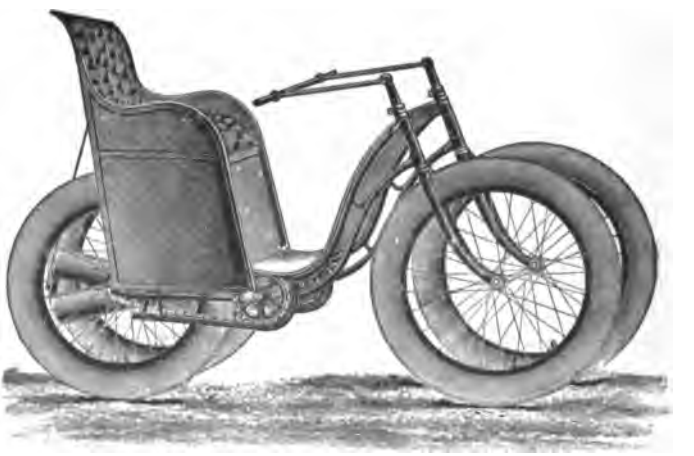
Another horseless vehicle is the invention of a Mr. Morrison, of Des Moines, Iowa. He uses a storage-

battery, and claims a speed of fourteen miles an hour and a capacity of running one hundred and eighty-two miles before recharging the battery.

Dr. H. C. Barker and J. R. Elbing, of Kansas City, Missouri, have constructed a carriage, using an electric motor designed by W. H. Blood, Jr., of the same place. They use a chloride accumulator of twenty-five cells, which can be stored with electricity at any electric-light or power station.

A. Schilling & Sons, of Santa Maria, California, have recently built a tricycle for three persons, operated by a two-horse gasoline engine, and carrying a twelve hours' supply of gasoline as fuel.

FIG. 25.



HITCHCOCK QUADRICYCLE.

The Hitchcock Manufacturing Company, of Cortland, New York, have placed a quadricyle and a bicycle on the market, both of which are operated by miniature motors.

The form of the quadricycle is well shown in the illustration. It has twenty-two-inch front wheels and twenty-inch rear wheels. Notwithstanding the fact that the motor develops five horse-power, the whole machine weighs only a hundred and fifty pounds, and makes very little noise. The seat is made wide enough for two persons, and the steering is accomplished by simply moving the steering-bar to right or left. The pneumatic tires are the thickest that have been seen on this side of the Atlantic, though vehicles are built in London with even larger diameter tire than these. The four-inch tires are said to make riding easy on the roughest roads. When the weight is on they cover about sixty square inches of ground, giving a surface that overcomes holes, stones, mud, or sand. They do not require to be as fully inflated as the small tires. The seat is so low that upsetting is out of the question. One gallon of naphtha answers for a trip of fifty miles. The makers say that it will go as fast as any one dares to ride. The same form of motor is used on the Hitchcock bicycle, which weighs only sixty pounds. The little oil-tank is on the top of the frame, between the saddle and the handles. It feeds a drop at a time, down through the hollow frames to the cylinders, one on each side of the rear wheel. Here the naphtha is mixed with enough air to cause a miniature explosion, when lighted by an electric spark, which gives the impulse to the piston. The tool-bag carries the battery that furnishes the electric spark. The motor is really a double engine of two horse-power. Either half can be laid off and the other will run the cycle, yet the motive mechanism only weighs twelve pounds, a remarkable lead over the French automobile carriages. The speed of the machine can be governed by the amount of oil let down, this being regulatable by a finger-rod on the

handle-bar. To start the machine the rider uses the pedals, at the same time turning the switch that starts the little battery to working. In an instant the power is developed, and he can coast away, leaving his feet on the pedals if he chooses, as they are set on with a ratchet mechanism so that they do not turn, but operate only as the feet are worked

FIG. 26.

HITCHCOCK BICYCLE.

up and down. The single gallon of oil in the tank will run the machine under favorable conditions for a hundred miles. The machine is suited to all weathers. When it is extremely hot the rider can cool himself in the breeze created by the motion. When it is quite cold, he can switch the exhaust air, which is hot, into the handle-bars and frame and warm himself. In dusty and muddy weather the large tires enable the machine to progress more easily than any other form of vehicle. An attachment for the front wheel, in the shape of a pair of adjustable runners, is designed for use in winter, when a sleigh-ride is desired. If bare ground is struck after a time the runners are switched up, and the journey continued on wheels. The frame is so low that the rider can place his feet on the ground in stopping or starting.

A tandem bicycle is also built on the same principle, with three seats, for lady, gentleman, and child. If this series of vehicles is all that is claimed, there would appear to be nothing more to desire, as the maximum of speed and comfort is provided for, and the cost of running is but a trifle.

At the Columbian Exposition in Chicago there were exhibited a number of electrically-driven vehicles, one being a three-seated wagon capable of travelling sixty miles. As it weighed two thousand pounds it was not considered practical. A quadricycle driven by gasoline was also on exhibition, and this was designed to carry ten people, itself weighing a thousand pounds, a figure which ought to insure its practicability.

Morris & Salom, engineers, of Philadelphia, have built an automobile carriage that is said to operate to their satisfaction.

The Holtzer-Cabot Electric Company, of Boston, have just placed on the market an electric carriage, built to imitate an English drag, and accommodating ten persons. It is driven by the chloride accumulator form of battery.

For several years past the Paris *Petit-Journal* has conducted competitions for automobile carriages, offering prizes to the most successful. Forty-two competitors entered in the race of 1894, showing how many concerns there are interested in the production and perfection of this form of vehicle. The petroleum-motor was the one most used by the contestants, and doubtless some form of oil-engine and the storage-battery will be the competing forms of motor in the near future. When acetylene gas comes into general use it will no doubt contest with these two for the supremacy. It is likely to prove the lightest fuel to carry, and will run small steam-engines to be used on car-

riages. For further information regarding this interesting gas see the chapter on "Illuminating Gas."

The Daimler motor, which was used on the four carriages whose builders divided the first prize at the Paris competition of 1894, is a two-cylinder gasoline motor, whose axis is placed parallel to that of the vehicle. Its rotating parts make seven hundred revolutions a minute, and are connected to the rear wheels through friction-gearing and a train of wheels that permits altering the speed in four gradations. The driver effects these alterations readily with a pedal. The brake which is made to go with this motor operates upon the hub or elsewhere, where it will not damage the rubber or pneumatic tire by being applied suddenly and with force. The Daimler motor is to be introduced in America the present year (1895) for driving pleasure and business vehicles.

The carriage which arrived first at the destination in the Paris trial of 1894, but which received only second prize because its design failed to fulfil certain conditions as to cost, was built by De Dion, Bouton & Co., and weighed four thousand four hundred pounds in running order. It was of the traction locomotive type, and exhibited a capacity of travelling eighteen miles an hour while hauling two thousand two hundred pounds over a level road. It is thought that the French army will adopt it for hauling light artillery.

Most of the vehicles in this Parisian competition were four-wheeled carriages weighing loaded over two thousand pounds. The exception was an eight-hundred-pound steam-carriage arranged as a tricycle, which received honorable mention. No electrically-propelled vehicles were entered in this contest, owing to the conditions imposed, by which they were practically ruled out. Since the contest, how-

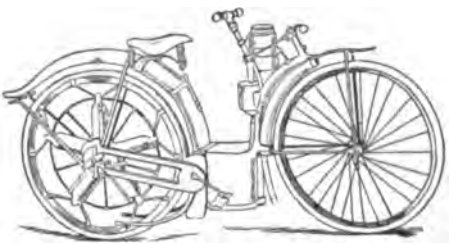
ever, a French inventor, M. Jeantaud, of Paris, who has been struggling with automobile carriages off and on for eighteen years, has perfected an electric carriage, run by Fulmen's accumulators, which marks a step of advance, although it is as heavy as the run of the French vehicles of this type. Ready for travel, with two passengers, it weighs two thousand five hundred pounds. The motor produces two and six-tenths horse-power at an angular velocity of twelve hundred revolutions per minute, but can be arranged to give out over four horse-power. The tests of this carriage showed that it would travel eighteen miles in an hour and a half on a level macadamized road before the accumulators required to be recharged. M. Jeantaud is not satisfied with this, and is constructing another carriage with a capacity of twenty-six miles of travel before being recharged.

The French competition of 1895 was arranged by James Gordon Bennett and Baron de Neufeldt, with a prize of forty thousand francs to the four-seated automobile vehicle making the best time from Versailles to Bordeaux and return, a distance of seven hundred and thirty-six miles. Minor prizes were offered for other types of vehicles. There were twenty starters. The fastest time was made by MM. Panhard & Levassor's two-seated petroleum carriage, which covered the distance in forty-eight hours and fifty-three minutes, including all stoppages. Les Fils de Peugeot Freres' four-seated petroleum carriage came in next, in about fifty-four and a half hours, and received the first prize. All the prize-winners used petroleum motors, carrying enough to run them about two hundred miles.

A gasoline bicycle of French manufacture was recently exhibited in the United States, attracting considerable

attention. Its mechanism is best shown by the accompanying sketch. There are five cylinders arranged spoke-fashion in the rear wheel, which is the driver. A small gasoline tank is mounted forward of the steering handles, and is carried down through the frame, as in the Hitchcock machine, being ignited in the cylinders by an electric

FIG. 27.



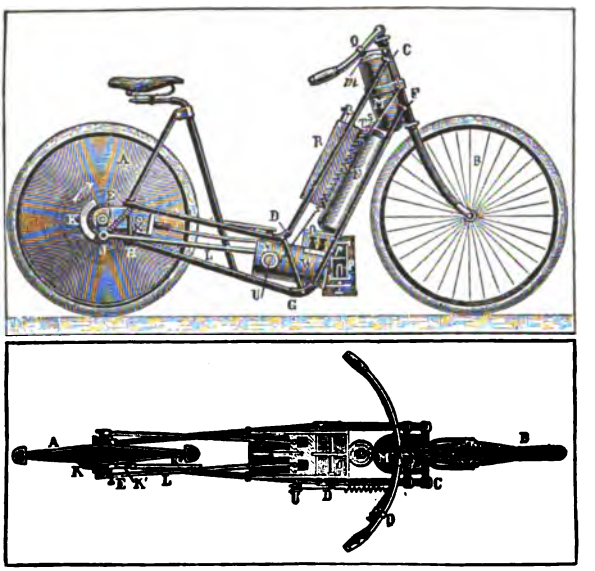
A FRENCH MOTOR BICYCLE.

spark at the rider's feet. Just how the gasoline gets to the cylinders, which are rotating with the wheel, or how they act on the wheel, is not clear. A pair of runners at the lower forward side of the rear wheel may be lowered to serve as a brake. The foot-cranks can be used when desired, but, as the machine weighs one hundred and forty pounds, this would not be very often unless the rider was fond of hard work. A speed of thirty-two miles an hour on a macadamized road is claimed for the machine. Until the weight is reduced it can hardly compete with the Hitchcock.

An interesting motor bicycle has recently been patented in Germany and has been introduced there and in France. Messrs. Wolfmuller and Geisenhof are the inventors. Its mechanism will be easily understood from the two diagrams appended, taken from *La Nature*. It will be observed that the rear wheel is solid, instead of being made

of light spokes. The reason given for this construction is that the little motor develops two and a half horse-power, and that if the rear wheel were made to weigh six pounds, as in many bicycles, there would be danger, in a wet spot, of its slipping and causing the engine to race in a danger-

FIG. 28.



WOLFMULLER & GEISENHOF'S GASOLINE BICYCLE.—A, driving-wheel; B, steering-wheel; C, D, E, F, G, H, frame tubes; M, gasoline reservoir; N, evaporator; O, valve box; P, lamp and ignition chamber; p, ignition tube; R, Water reservoir; S, cock for regulating the entrance of gasoline into the evaporator; T, funnel of the evaporator; U, regulator of water for cooling cylinders; V, distributing mechanism; W, cylinders; I J, connecting rod; K, cam; K′, roller; K″, rod of the distributing mechanism; L, piston.

ous manner. It is necessary to oppose more resistance to the pistons. The mechanism is covered with wire guards, not shown in the accompanying illustration because they obscure the parts. This bicycle weighs one hundred and ten pounds, and the touch of a button serves to vary its

speed from three to twenty-three miles an hour. The inventor exercised some ingenuity in making use of the hollow tubes of the frame (which is double) to circulate water for the cooling of his cylinder. The gasoline reservoir is said to contain enough fluid to furnish means for one hundred and twenty miles of travel. It must be confessed that it looks small for such a claim. The gasoline is vaporized, drop by drop, and mixed with air in the driving-cylinder, as in the gas-engine, a small lamp being provided to explode the mixture. On the handle-bar is a thumb-piece by which the rider controls the operation of the motor. It is true that the mechanism of this bicycle appears a trifle too complicated, but it is probable that it will be simplified as it comes more into use. It is already an assured success on the Continent, and will soon find its way to America, unless some of the home inventions prove better.

While speed is a desideratum in all these vehicles, it is probable that the public will not demand great velocity, but rather give preference to the vehicle that will show the greatest carrying capacity at about eight or ten miles an hour. That is fast enough for street travel, and in most cities the speed is restricted by local ordinance to ten miles an hour. The vehicle that will carry four persons most economically at a speed of ten miles an hour will have the call.

In England electric carriages are in a more forward state than in America. The better roads there have induced the manufacturers to take hold of them more promptly. Already storage-battery vehicles are in use in London, and Radcliffe Ward has begun to operate carts and express-wagons on the streets with electric motors. An electric power-station is being erected in that city for

the special purpose of charging the batteries used by such vehicles, and it will not be long before the same thing is done in the large cities of the United States.

It is pertinent to remark here that these vehicles are considered much safer than horses. Most of our street accidents (barring the reckless trolley) come from the unmanageability or fright of horses. The automobile vehicle never gets frightened, and its driver is sure to be at least as good as the driver of the average horse. Since they can turn out and be stopped promptly, there is no prospect of any repetition of the murderous record which has been made in several cities by the criminal disregard of human life among street-railway managers.

As proof that the days of the horse as a motive power are numbered, it is sufficient to note that the breeding of common horses in the United States has practically ceased, owing to the fact that the prices obtainable are no longer remunerative, a sure sign that the market is overstocked. More than half the street-cars of the country are now operated by other means, and the lesser half are only waiting for needed legislation to enable them to do without the horse. It is estimated that over one hundred thousand of these animals have been dispensed with in ten years in the United States alone. The saddle-horse has almost disappeared before the bicycle, and the driving-horse is about to be ushered out by the automobile carriage. The cabbies of the twentieth century will all have vehicles of this class, and they will no longer stand in awe of the agents of the societies for the prevention of cruelty to animals. There will be no more elopements of the daughters of aristocracy with the family coachman, for the ladies will usually prefer to do their own driving. The express companies will hail the innovation as a boon, and neglect to put down their

rates. The public will adapt itself to the changes as calmly as it accepted the telephone or the trolley, and everybody will be better off. But does it not seem funny to think that our grandchildren may live to see horses exhibited in museums as curiosities?

BICYCLE MANUFACTURE.

Ingenious Mechanisms contrived to cheapen and improve the Steel Steeds—Severe Tests to which Material is subjected.

THE bicycle is a very simple machine in principle, yet its manufacture has been brought to a degree of perfection perhaps only equalled in the case of the watch. The necessity for lightness has caused an excellence of workmanship and a carefulness of detail to be found only in the highest class of machinery. When the modern rubber-tired machine was first introduced, about 1870, well-made machines weighed from sixty to seventy pounds, and no American rider was able to cover a mile inside of three minutes on one. To-day twenty-pound wheels are common, and wheels of less than ten pounds weight have been built for exhibition purposes. The speed is correspondingly reduced, a number of riders being credited with a mile inside of two minutes. In order the better to understand how such a perfect machine can be made, it is advisable to give a detailed description of the methods employed by the best makers. Some of the special machinery invented to aid its production is almost as remarkable as the bicycle itself.

For the manufacture of hubs a reproducing lathe is used, having guides by means of which each hub is turned

to exactly the same shape as others of its kind. The blank is usually made of bronze or mild steel, and has been stamped to a close approximation of its form before going into the lathe to be finished. In boring the hub to receive the spokes, the hub is mounted upon a dividing-plate that insures the accurate spacing of the holes without effort on the part of the operator.

FIG. 29.

THE WAVERLEY AXLE.

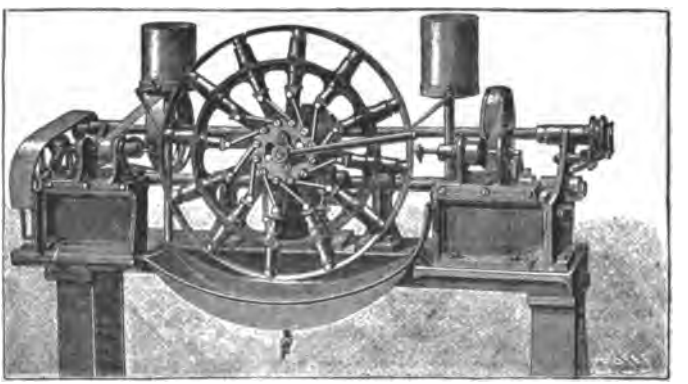
For the spokes the wire-makers draw a very tenacious steel, which for straight spokes has to be upset, or thickened on the end, so that it will not be weakened by threading. The rim end of straight spokes is usually simply spread so that it will not slip through its hole. The tangent spokes, which by reason of their braced arrangement may be made of lighter wire than the straight spokes, are usually connected with the hub by a head and with the rim by a nipple.

Rims are made either of selected hickory or of bar steel rolled to the desired thinness and brought to a curve by running between grooved rollers. The ends are sometimes united by brazing, but the latest and preferred method is electric welding. This unites the ends so perfectly that the place of junction is lost so as to be afterwards unobservable. The machine used crowds the opposed ends together, while an electric current heats the parts to a welding temperature. A most ingenious machine has been invented for boring the rims. It will be readily under-

stood from the cut. The drills operate from the exterior of the rims, and the interior braces are adjustable to any of the common sizes of wheel, and serve as guides in drilling.

The hub, rim, and spokes, being finished, go to an assembling-room, where a workman puts them together, and with infinite patience tests and tries each spoke by tightening and loosening until the wheel is exactly true in form.

FIG. 30.



RIM-BORING MACHINE.

The steering-bar is usually of hollow steel drawn very thin, and rendered conical towards the ends by hammering with a steam-hammer. Many makers curve it while cold by filling it with a powder that prevents distortion while bending.

The steering-fork is made in several parts, the crown being drop-forged or made of brazed pieces of sheet steel. The sides of the fork are flattened tubes, tapered in a machine made for the purpose.

The cranks are simply made, being drop-forged from a good quality of spring steel. After forming they are hard-

ened by a slight tempering, so as to bear a strain of about six hundred pounds. The slotted hole in the crank is made with a milling machine, the crank being fed forward slowly until the hole is lengthened as far as desired. The attachment to the crank-shaft is accomplished by tapering the latter into a square end, or by means of a pin or key. The latter method is usually preferred. The key has to be made exceedingly hard to withstand the strain.

Sprockets are made of drop-forged steel, the teeth being accurately cut later in a machine similar to one for cutting gear-teeth. They are screwed onto their hubs in such a manner that the running of the bicycle tends to tighten them. Some makers build the forward sprocket in one piece with the crank, a most desirable arrangement.

Chains are usually bought from chain manufacturers, and some of the bicycle-makers use a machine for limbering them up to secure easy running. On one of these six sets of sprockets are set up and chained at a time. They are run for an hour under a considerable strain, after which they will go like "greased lightning."

Ball-bearings have been so much written about as to have become familiar to all. They are now used all over the bicycle. About ten are used at the end of each hub, twelve to fifteen on the end of each crank-hanger, twenty to forty more in the steering-head, and about twenty-five in each pedal, so that the total number in a good bicycle varies from one hundred to one hundred and fifty. They are excessively hard and are ground to shape between oppositely rotating disks. In these disks are grooves in which the balls are revolved along with emery powder. There is a tendency of late towards the use of larger balls, which it is thought reduce friction more than the smaller sizes. Some builders make them as large as

three-eighths of an inch in diameter. The cups in which the balls revolve are made separate from the hubs or other portion of the machine in which they are placed. This is done for convenience in tempering. The object in tempering is to secure hardness. The disadvantages of tempering are increased brittleness and a slight distortion of the part. The distortion involves shaping again in the lathe. This is extremely difficult, because the tempered cup has already been made almost as hard as the tools with which it is to be turned down. Manufacturers have succeeded in making extra hard tools that will cut the cups, though the tools are necessarily very brittle and subject to breakage.

Special lathes are made for turning several axles at once. Some of them are fitted with bells to notify the workman in charge, who has to look after several machines, when it is necessary to readjust the tools.

The tubes composing the main frame are made of cold drawn steel. That is to say, they are drawn through dies that reduce their thickness and tend to concentrate and harden the metal. These tubes are cut off to the exact length required, in a machine designed for the purpose, that severs them with a clean, smooth cut. The joints are drop-forged and bored out in a special lathe that has an adjustable jaw on the face-plate for holding the part to be bored at the desired angle against a drill fixed in a centre. Another special machine shaves out, with a single cut, the cavities that hold the ball-cups. The putting together of the parts of the frame demands very careful workmanship. The tubes are now made so thin—being about like thick card-board—that the joinings with the connections must be perfect, and so accomplished as to avoid twists and strains that injure the steel and shorten its life. The parts are set up in a jig or framework that holds each piece in exactly

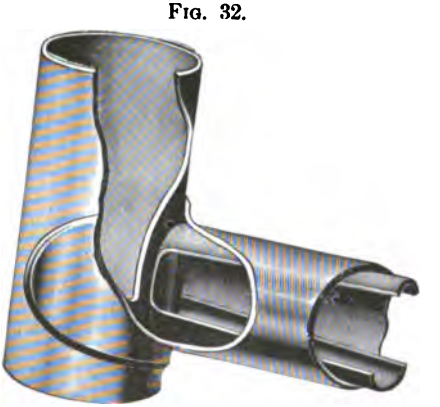
the required position. A gas blow-pipe is then employed to braze the parts together. The Waverley method is here

FIG. 31.

BRAZING A BICYCLE FRAME.

illustrated. Brazing is not equal in strength to welding, therefore the joints are lapped to allow of the brazing of a

FIG. 32.



THE WAVERLEY BRAZED JOINT.

larger surface and to get greater strength. Borax and zinc are used to assist the brazing, and when the work is done

and cooled it is washed in acidulated water to remove the borax. The frame then goes to a filer, who smooths up the joints, taking extreme care not to weaken them. The frame is then polished with an emery stick and brush, and enamelled.

For pedals, the rat-trap styles are becoming more common than the rubber. They are made of sheet steel, stamped into a pattern. The foot-rest also is usually stamped, as well as numerous minor parts which are cheaply formed in this way.

The saddle-post, in the best makes, is hollow, and of T-form. The saddle-springs are made in so many patterns that no shape can be said to be standard. Any one of a dozen forms gives equally good results. Two wires, with numerous curves, form the prevailing types. The wire is of the best spring steel, and has to be very accurately tempered. Some ingenuity is exercised in attaching the leathern saddle to its springs by riveting in such a manner as to avoid tearing the leather, or straining it unduly in any part.

Before nickel-plating or enamelling, the parts of a bicycle must all be polished, first with a coarse emery-wheel, then with a fine one, and lastly with a revolving brush, using emery putty. Being well cleaned, and rubbed with rotten-stone or Tripoli powder, and washed, it is ready for the galvanic bath, in which it receives a thin coat of nickel. After nickel-plating the parts are rubbed with sawdust and a pasty cloth.

During the process of manufacture of high-grade bicycles, every piece and part is subjected to the most severe tests and examination. The steel bought comes in batches into the testing-room. One piece of each lot is subjected to tortional strains to see if it comes up to the required

standard, or at what point it will break or twist before becoming permanently distorted. Another piece is tested for compression, and another strained lengthwise to the point of rupture, and so on until the tester is abundantly satisfied that every piece of metal in the lot is up to grade. If some of it falls below grade he orders the whole lot destroyed. Finished parts are subjected to the same sort of usage, to see that they have not been unduly weakened. This costs a good deal of money, and results in the wasting of some material, but it saves the bones of bicycle riders, and explains why it is sometimes cheaper to buy a high-priced wheel. You may get as good material in a cheap wheel, but the chances are that you will not.

Pneumatic tires are made in several different ways, and there are various patents dealing with their construction. Removable tires are liked the best. Some of them are simply endless tubes hooked into the hollow of the rim. A good form consists of an inner tube rendered air-tight by rubber and protected by an outside cover or shoe which is open all the way around on the inner side, and fastens into the rim by projecting flanges which pass under the turned-over edges of the rim, and are held there by the pressure of the tire. This tire will remain on the rim even when exhausted of air. The best air-tubes are made of pure rubber, and are moulded in two or three layers, so that the joints of the layers come in different places. The fabric used in the outer case is a high grade of cotton.

The setting up of a completed bicycle is no small task. It is well known that any machine when first put together runs hard until the parts become so adjusted together as to run perfectly. Purchasers of bicycles will not allow for any such "working easy" after use. The bicycle must be made to run easily and perfectly before it leaves the shop. This

requires patience and perfect adjustment. The fitter-up in time acquires an intuitive sense that guides him to the cause of the trouble when a machine runs hard.

The lamps, bags, and etceteras of a bicycle are frequently purchased wholesale, to avoid the nuisance of cluttering up a shop with too much trifling machinery.

COMPRESSED-AIR MECHANISMS.

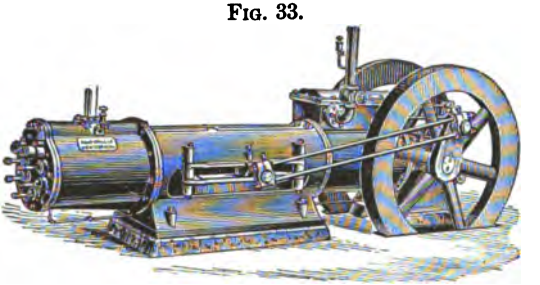
A Synopsis of the numerous Uses to which this Form of Power is being applied—A Competitor of Electricity.

AIR is a subtle and elastic fluid, and it is not surprising that its use as a motive power, and for various mechanical purposes, should have grown to enormous proportions without attracting wide attention. Certain it is that no one not intimately familiar with the history of compressed air during the past dozen years has any conception of the extent and variety of its uses. This may be the age of electricity, yet compressed air is coming into use for purposes entirely similar; in fact, it steals in where electricity leads the way. The power of compressed air was known long before we began to understand that the electric current could be made useful, yet air as a motive power for railways, and in shops for driving tools individually, has only come to be used after we had tried electricity and found that such installations were convenient and economical.

The machine that renders air serviceable as a motive power is called an air-compressor. It looks much like a steam-engine, and usually there is a steam-engine cylinder incorporated in its mechanism at one end of its bed, while

an air-cylinder occupies the other end. At every stroke a cylinderful of air is compressed by a piston and driven out through a large pipe, the action being the reverse of that by which steam drives the piston in its cylinder.

FIG. 33.



THE RAND DIRECT-ACTING STEAM AIR-COMPRESSOR.

The best forms are of the horizontal duplex type of steam-engine, with air-cylinders behind and in line with the steam-cylinders, and so coupled that one piston-rod serves for both cylinders.

Storage-tanks of compressed air for use in driving street-cars are quite as much in use as are storage-batteries for the same purpose. Air is so used to-day in France on a line between Paris and Nogent-sur-Marne and on the Nantes Railway. The Paris road is operated by about six large tanks per car, each set of tanks containing a supply of compressed air sufficient to carry the loaded car over five miles of graded road, or about eight or nine miles on a nearly level road. As a matter of fact, however, the cars are recharged at stations about one and a half miles apart. They have the advantage of being smokeless, also of making very little noise and dirt, while their independence of a locomotive or of wires is a material advantage. Each motor on the Paris line carries a pressure of two thousand

pounds to the square inch. A simlar railway is operated at Berne, Switzerland, with a storage capacity of only three hundred and fifty pounds pressure. In either case the air is used through cylinders, as in a steam-engine, at pressures of about one hundred to one hundred and seventy-five pounds.

There are no such railways in America, but a syndicate has been formed to introduce them. A new line is now (1895) in progress in France between the Louvre and St. Cloud. Here atmospheric locomotives will be used to draw trains of three or four cars each.

European nations have been more prompt in seeing the usefulness of compressed air than have Americans. Most of the large cities on the other side have systems of pneumatic tubes for the delivery of small packages. The Paris installation is the largest, and is operated on the plans of M. Victor Popp. The company sells compressed air as electricity is sold in the United States. They supply pressure to about two thousand pneumatic clocks, to several street-railways, to refrigerating establishments, and for utilization as power in driving machinery. It costs them only ten cents for every three thousand cubic feet of compressed air delivered to customers. The London, Berlin, and Vienna pneumatic-tube services are used principally for letters and small packages.

In the United States there are but three cities having a system of pneumatic tubes worthy of the name—viz., Philadelphia, Chicago, and New York. Philadelphia's system makes use of the largest pipes known to such service, six and one-half inches being the diameter. The plant was installed in 1893 for the use of the post-office in delivering packages to a substation half a mile distant. It is to be extended for the convenience of the business

public. Chicago has a short pneumatic-tube system, connecting the newspaper offices and press associations. New York has one owned and operated by the Western Union Telegraph Company for assisting the delivery of its messages between up-town and down-town offices.

Compressed air is probably used more in mining enterprises than in any other business. No mine worked on a sound basis, situated within five miles of an effective water-power, should be without its air-compressing plant, located at the fall, and utilizing the power to compress air and send it to the mine to work as much of the machinery—drills, pumps, engines, hoisters, etc.—as the power will allow. The splendid success of the Hydraulic Power Company, of Michigan, in leading air three miles from the Quinnesec Falls to Iron Mountain, to drive all the machinery of the Chapin and Ludington iron mines, is the largest and most striking proof of this fact.

When competent engineers assert that compressed air can be delivered for utilization as power at a cost not exceeding twenty-one dollars per horse-power per year, it is evident that it has a future in cities, where power is commonly sold at from sixty to one hundred dollars, or even more, per horse-power.

The compressed-air rock-drill came into use about 1865, and by its aid the great tunnels of the world have been built—that is to say, the blasting-holes have been bored by the rock-drill, to which compressed air was supplied through the convenient medium of a hose.

Railroad shops are introducing compressed air extensively to operate cranes, hoists, and machine-tools generally. It is liked because it is convenient, and because it lends itself to a variety of peculiar uses, such as hoisting oil from barrels by turning in a stream of air, the cleansing

of steam passages, and even for running letter-copying presses in the offices. Another novel use is the sweeping and dusting of railway cars, shops, etc., by means of an ordinary hose. Car-cushions are thus cleaned better and quicker than by beating. A dump-car has been invented recently that is operatable from the locomotive by means of the train-pipe. A ten-inch dumping cylinder is placed under the car, after the manner of the air-cylinder of an air-brake. Numerous safety appliances for railroads are operated by air, as switch and signal systems, etc., its reliability being held in esteem. In winter, alcohol is introduced in the exposed pipes of such systems to prevent freezing.

Many portable tools are operated by compressed air. Convenient drills have been recently introduced for metal-boring, the power being applied through a rubber hose, enabling the user to place the tool in any position. War-ships have been calked in the Cramp's ship yards for three years past by air-calkers, one of which does the work of four men and does it better. Boilers and tanks are calked in the same way, and makers are glad to be rid of the unevenness incident to hand-calking.

A considerable revolution is likely to be worked in the business of dressing marble and hard stone by an air-driven portable tool introduced in 1894. A long adjustable horizontal arm bears a reciprocating piston with a tool. By a succession of rapid blows a stone may be surfaced nearly ten times as fast as by hand. Ornamental carving and lettering is also done by a similar tool, and it is possible to reproduce bas-reliefs in marble from dies—a thing never before accomplished.

A recently-patented invention that promises much is a system of moving fluids automatically by compressed air.

In the case of an artesian well, a small pipe is run down to introduce the air at the bottom of the large pipe proper. In rising through this large pipe the air carries the water with it, thus dispensing with plungers, buckets, etc. Objectionable mud and sand are got rid of by simply blowing them out. This system has been introduced for local waterworks at Rockford, Illinois, and at Wayne, a suburb of Philadelphia.

The fog-siren, for warning vessels off a coast, or the like, is often run by compressed air. The French have discarded steam for this purpose as inconvenient. They now use the air at a pressure of only twenty-eight pounds, having tried various higher pressures with less satisfactory results.

A large machine-shop in St. Louis has been fitted up entirely with compressed-air apparatus, a twenty-ton crane and the smallest tools being alike connected with the reservoirs. The larger tools have their own individual motors, which are started by turning on a cock. There is thus no necessity for idle power. Shafting is dispensed with except in cases where several small tools are connected with one motor.

Riveters and stay-bolt cutters, as used in bridge construction, are now frequently run by compressed air. The Liverpool electric overhead railway was put together with a pneumatic riveting plant, the air-compressor being mounted on a track and run along the rails. In this work it was common to put in three thousand two hundred and forty rivets in ten hours with one machine.

Compressed air is used to spray petroleum for boiler-fuel, and has the advantage of furnishing a uniform heat, regulatable by a cock. In tempering, welding, japanning, etc., this aërated petroleum spray is much valued. Water-

supplies for cities are also aërated, as at Little Rock, Arkansas, by means of air-compressors. By using both filters and an aërating plant, a very poor quality of water may be made fresh and sweet.

Asphalt requires agitation at the boiling-point for several days during process of manufacture. Compressed air is the only satisfactory agent for this purpose. The mixture of acids in compounding nitro-glycerin is also best accomplished by a similar process.

The brilliancy of lamps is often increased by a draft of air, as noticeably in the lucigen, which employs a pressure of thirty pounds to atomize the oil. Paint is also atomized, and put on with a little nozzle at the end of a hose, being fairly driven into the wood if desired, or sprayed on in the most delicate manner if for tinting or the like.

Cellulose silk is made from wood-pulp by air pressure, being forced out of minute holes in a tiny thread, six of which have to be twisted into one before it is fit for weaving. Wood already forms the principal constituent of our paper, and, if this invention prospers, it may also furnish us with clothing.

When natural gas wells weaken, an artificial pressure of air may be used, thus enabling the gas to be distributed to a distance impossible by the natural pressure. Compressed air is also used to raise sunken vessels, in numerous ice-making and refrigerating plants, and in pneumatic tires. A London concern has even introduced a pneumatic wheel. It is a hollow, flattened, spherical chamber, made of tough material, having two metal side-plates, and a hollow centre for the axle. A vehicle wheel thirty-one inches in diameter is eleven inches thick. They are said to make riding over cobble-stones a luxury.

Other and more familiar uses of compressed air deserve

only a passing mention. The air-brake has ceased to be a novelty. The pneumatic or dynamite gun is described in another chapter of this work. Air-cushions have been used for invalids for many years, and blowers have become so common that the inventor is forgotten. Probably the reader is already convinced that compressed air is destined to increase in use, since it is so peculiarly convenient and can be distributed with so much economy.

THE CHAINING OF NIAGARA FALLS.

The Mightiest Water-Power of the World at last trained to serve Mankind—Details of the Construction and Power-Plant.

THE utilization of a part of the power which has been going to waste over the greatest falls in the world is not a remarkable thing in itself. The real wonder is that it should have been so long delayed. While minor water-powers have been developed all over the land, and most of them fail at times to give the desired flow, here is one universally known to be constant and practically exhaustless, which has remained untouched until 1889, and is only partially available for use in 1895. So long since as 1847, Judge Augustus Porter commented upon the desirability of making use of the Niagara power, and issued a circular setting forth its advantages, and outlining a scheme for establishing a system of canals and wheel-pits to distribute the power for use at moderate distances. Nothing came of it, and it was not until 1886 that the matter received that general attention which presaged success. In that year the New York Legislature was asked to charter the Niagara Falls Power Company, the prime movers in the matter

being citizens of the locality, who had become enthused over a plan laid out by Thomas Evershed, M.E., of Rochester, New York.

That a charter and a scheme will not erect a plant and start business was demonstrated to the promoters of the enterprise during the next three years, which elapsed before

FIG. 34.

THE TAIL-RACE TUNNEL.

the money was forthcoming for active work. In 1889 the Cataract Construction Company was formed by capitalists of New York City, and entered into a contract with the original company to equip a plant that should develop one hundred thousand horse-power. Later, the Niagara Development Company and the Niagara Junction Company were organized to develop the land adjacent and construct railway conveniences for manufacturers. They acquired two and a half square miles of land on which manufacturers have been invited to locate, with the surety of obtaining cheap and reliable power for driving their machinery.

The general plan adopted for utilizing the power is quite simple. A main canal leads the water from above the

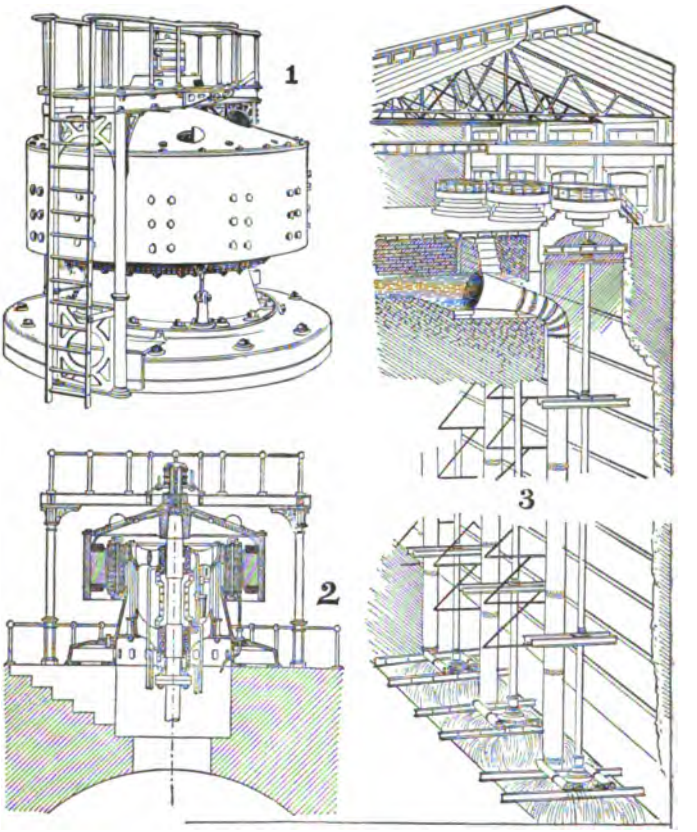
falls to a power-house, where the water takes a drop of one hundred and thirty-six feet through great pipes onto turbines, which in turn convey the power to the surface by means of shafting connected with vertical dynamos, from which the power is distributed by wire to any desired locality within a hundred miles or so. As the wheel-pit is made very long, new turbines and connections can be added as wanted. This arrangement was not decided upon without calling into consultation the most experienced and well-qualified engineers of the world. A commission was called together in London to decide on the best plans, and its members were Lord Kelvin, of England, president; Professor Cawthorne Unwin, of London, secretary; Professor E. Mascart, of Paris; and Dr. Coleman Sellers, of Philadelphia. The only means seriously discussed for distributing the power were electricity and compressed air. The results to be obtained were figured as about the same, and probably the reason why the commission decided upon electricity as the best means was because its possibilities of development in the future were considered greater than those of compressed air. There is not good reason for supposing that we shall discover many improvements in methods of using compressed air, but there do exist good reasons why we may expect material simplification of electrical appliances, as we learn more about them.

The average fall of water over Niagara, according to careful estimates, is nearly sixteen million cubic feet per minute, or eight and a quarter millions of horse-power. By extending their system the Niagara Falls Power Company could eventually secure four millions of this horse-power, the larger half being lost because the company only makes use of one hundred and thirty-six feet head, while

the Falls and Whirlpool Rapids together give a head of two hundred and seventy-six feet.

The first power-house erected by the Cataract Construction Company has or will have a capacity of fifty thousand horse-power. It is located on what is called the main canal, about a mile and a half above the American Fall. This canal is about a quarter of a mile in length, and one hundred and eighty-eight feet wide and seventeen feet deep at the river end, tapering to a width of one hundred and sixteen feet. It will carry twelve feet of water, as a rule. The walls of this canal are constructed of solid masonry, seven feet thick at the bottom and three feet thick at the top, the stone coping being two and a half feet wide. The wheel-pits are arranged parallel to the canal, with which they are separately connected by conduits. The first of these wheel-pits is one hundred and seventy-nine feet in depth, one hundred and forty feet long, and twenty-one feet wide. Its arrangement is shown in the illustration. The digging of this wheel-pit involved much labor, since it is blasted from the solid rock. The ragged sides are protected in the most substantial manner with heavy masonry. It is designed for eventual extension to a length of two hundred and sixty feet, and after such extension proves inadequate a second power-house and wheel-pit will be added, which will use all the present capacity of the canal. For further increase of power the canal will have to be extended. The tunnel for the discharge of the water from the wheel-pit is more than a mile and a quarter in length, emptying into the river below the Falls. Its horseshoe section will be observed in Fig. 34, also a hint as to its construction. The extreme height is twenty-one feet and the greatest width nineteen feet, giving a capacity of three hundred and eighty-six square feet of section. The concrete casing

FIG. 35.



1. THE FIVE THOUSAND HORSE-POWER DYNAMO. 2. CROSS-SECTION OF SAME. 3. INTERIOR OF POWER-HOUSE AND WHEEL-PIT.

is made of one part Portland cement and three parts gravel. A track extends through the conduit, having been laid for the convenience of the workmen in building. The grade is very slight, being only a trifle over thirty feet for the whole distance, but it is calculated that it will deliver over

six hundred thousand feet of water per minute, a quantity that will develop somewhat over one hundred thousand horse-power at the head here obtained.

The power-house is an L-shaped structure over the wheel-pit, on the west side of the canal. It is a stone building, with steel frame and roof, the latter having sixty feet span. The principal entrance is a large archway that will admit a railway-car. To the left of this are the offices, which are arranged in four stories in the L. The power-house proper is one large room, so arranged that the great fifty-ton travelling-crane can be used to lift machinery at any part of it. Here we see the row of dynamos or generators, over whose selection there was so much controversy. The illustration gives both an interior cross-section and an exterior view. These dynamos were of necessity constructed under severe limitations, being required to deliver five thousand electrical horse-power, with a fly-wheel effect of five hundred and fifty thousand tons, and not to rest more than forty tons of weight on the shaft. A variety of plans were offered the company, which rejected them all, and gave the design into the hands of their consulting electrical engineer, Professor George Forbes, who evolved the design here shown. Several of the engineers who submitted designs have protested that the design used was but a utilization and combination of the best points in the designs offered. However that may be, the dynamos are quite different from any before constructed, as might be expected from the unusual condition of building them on vertical instead of horizontal shafts. In order to obtain the necessary fly-wheel effect, the fields are made to rotate outside of the stationary armature. A two-phase alternating current is used, of low frequency. The potential may be as great as two thousand four hundred volts. The design

was somewhat modified by the engineers of the Westinghouse Electric and Manufacturing Company, who built the first three dynamos, before they would guarantee their efficiency.

A difficult problem in the arrangement of the installation was the taking care of the forty tons' weight of the dynamo, with thirty-six added tons of shafting, etc., together with the enormous downward pressure of the falling water in the pipe or penstock. This was solved by closing the bottom of the casing, so that the water cannot act downward upon any of the parts attached to the shaft, while in the upper end of the casing are apertures, through which the water can act upon the under side of the disk carrying the movable blades of the upper turbine, and relieve the bearings of the weight of the shaft. In this way the pressure due to the head of water is made to act upward and assist in supporting the rotating shaft, while the weight of the water column is sustained by the stationary structure. These turbines are made of the same quality of cast bronze that is used in propellers for ocean steamers. They are of the outward-discharge pattern, having the buckets divided into three sections, so that the same efficiency can be obtained at the opening of a part of the gates as if the whole are opened. These gates are operatable from above, both by the governor and by hand. The speed of revolution is two hundred and fifty a minute, and the diameter five feet three inches, which seems very little when we reflect that each will develop five thousand horse-power. Though the wheel-pit is one hundred and seventy-nine feet deep, the available head is but one hundred and thirty-six feet, measured from the surface to a point midway between the opposed wheels. The vertical shaft that makes direct connection between the turbines

and dynamos is a rolled-steel tube of thirty-eight inches diameter, reduced to eleven inches of solid steel at the bearings.

The Pittsburg Reduction Company has erected a plant about two thousand five hundred feet from the power-house, where they will manufacture aluminum, using about three thousand horse-power. The Niagara Falls Paper Company is also located there, and will use nearly as much power. Various other concerns are negotiating for the location of factories, including one to make calcium carbide for use in manufacturing acetylene gas.

The city of Buffalo, which is but eighteen miles from the Niagara Falls Power Company's plant, is to be supplied with electricity direct. Their water-works will be furnished at a charge of twenty dollars per annual horse-power, and arc lights maintained for fifty dollars a year. The city's contract reserves the privilege of buying the local plant at the end of twenty-five years, and stipulates for one price to all consumers, large or small.

The future of the Power Company is regarded as very bright, and the original investors should reap large rewards. It is thought that in time they will be able to deliver power to New York City at a rate commercially profitable. With present appliances the leakage of such a line would be too great to maintain it with profit, even if the theoretical first cost of the power was only represented by moderate interest charges.

It is interesting to note in this connection a near-by electrical enterprise, at present only proposed, but which, if it goes through, will undoubtedly prove a customer for power. Some genius has designed an aërial electric railway and organized the Aërial Tramway Company. They have petitioned the New York Legislature for permis-

sion to establish a landing-place and a tower in the State Reservation Park to carry one end of their cables. They already have permission from the Canadian government to erect their conveniences on that side of the river. If they secure the desired privileges, they will carry passengers over the very brink of the cataract, and only thirty feet above it. A double set of cables will be stretched from the towers in the Canadian and American parks, with a supporting tower on Goat Island. On these cables cage-like cars will be suspended by trolleys, and operated by electricity from the American side. The aërial line will follow along the brink of the American Falls to Goat Island, and thence to the Canadian shore, forming a sort of cord to the bow of the Horseshoe Falls. The cars and cables will be of steel. The car-floors will be so perforated that tourists can look through below without leaning over the sides. If properly constructed, this aërial tramway, as the projectors choose to call it, will be as safe as any suspension bridge, and its extreme novelty will insure its success as a commercial venture.

IMPROVEMENTS IN TELEGRAPHY.

A Practical Printing Telegraph already in Operation, and a Pictorial Telegraph that reproduces Engravings is coming soon.

SAMUEL F. B. MORSE did a great deal for the world by his inventions pertaining to telegraphy, and J. H. Rogers, of Washington, promises to double the utility of the telegraph as an adjunct to modern business conveniences. The Morse alphabet is simple and easily learned, but the operation of sending a message by means of its characters

has proved sufficiently difficult to require the aid of trained operators. Mr. Rogers has devised a system by means of which an ordinary typewriter may be used with an attachment that punches a paper tape. This tape is taken to the telegraph office and run through a machine, whose operation is synchronous with a machine at the receiving station, where the message is automatically printed, and delivered to its destination in the form of a letter. This system gives

FIG. 36.

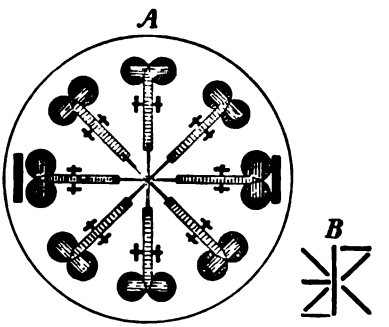
ROGERS'S TYPEWRITER PREPARING TAPE.

a speed of two hundred or more words a minute, which is as fast as a person can talk who desires to make himself understood. It has the added advantage of insuring the correctness of the message. No repeating at double price is required to insure accuracy. The message received must be the same as that originally written on the typewriter.

This system is now actually in operation between Washington and Baltimore by the United States Postal Printing Telegraph Company, and seems destined to have

a wondrous growth. Though simple in its results, it required twenty years of patient experimentation to bring it to perfection. In order to simplify transmission the

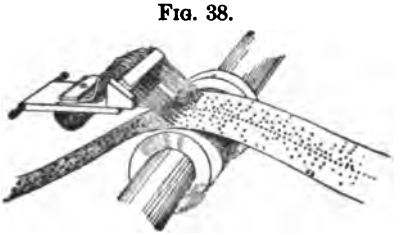
FIG. 37.



A, PLAIN VIEW OF TYPE ARMS; *B*, FACE OF TYPE MAGNIFIED.

alphabet was reduced to eight characters. Every letter known to the English language is composed by these eight little marks in a manner wondrously simple, when you

FIG. 38.



ROGERS'S TRANSMITTER.

see how it is done. These eight characters are arranged on radial arms, and so attracted by magnets that they strike combinations giving the different letters, which are punched in a tape connected with the typewriter. The

tape is then run through an automatic telegraphic transmitter, as shown in the illustration.

The process of telegraphing is to slip the perforated tape on a small rotating cylinder under a row of metal points or brushes, so that each of them may drop into the holes

FIG. 39.

ROGERS'S SYNCHRONOUS WHEEL RECEIVING.

on its line, the holes representing the letters, so that at every rotation of the little cylinder a current passes over the line which is calculated to operate the impression of the type at the other end by means of magnets. The illustration shows the stylus points and perforated strip on the

cylinder. The centre holes serve to guide and regulate the movement of the tape automatically, so that no manipulation is required to assist the operation. By means of synchronous wheels at either end of the wire the message is repeated at the terminus by a process too complicated to be here described. Suffice it to say that Mr. Rogers calls it visual synchronism, and that the receiving operator assists the synchronism of the wheels by occasional pressure with his thumb, when he observes that they are getting out of regularity. In this manner he has succeeded in receiving as many as five hundred words per minute, but only two hundred are claimed as an average durable speed. The receiving operator has nothing to do with the receipt of the message but to keep his wheel in unison with the sending wheel. If he does that the message is bound to come out all printed as sent.

For assisting long-distance transmission an automatic relay has been devised that responds to impulses representing the vibrations of the musical sounds. If this system proves to be all that its promoters claim, it is likely to revolutionize the postal system as far as business communications are concerned.

A kindred invention is that of N. S. Amstutz, of Cleveland, Ohio, who has devised the electro-artograph, a mechanism for transmitting copies of photographs to a distance by means of the electric wire, and reproducing the same at the receiving station in the form of a line engraving ready for the printing-press. The whole operation is so simple and quickly performed, and the results are so excellent, from an artistic stand-point, that the process seems likely to come into use for mechanical engraving without any distance transmission, as it is much quicker in operation than any of the processes now in use. The success of the method hung

upon the synchronous motion of two cylinders, as with the Rogers invention, and Mr. Amstutz claims to have overcome all difficulties in this direction. Certain it is that the work he exhibits as done by his machines in his laboratory is good enough to print in any periodical, and vastly better than any of the crude attempts previously offered the public.

In this invention the undulatory or wave current is used, as in the telephone, and the transmitting and receiving apparatuses each bear synchronously rotating cylinders. On the transmitting cylinder is mounted a prepared gelatine film, whose construction will be understood by reading the chapter on photo-mechanical processes. This gelatin film has been hardened, and presents a surface of elevations and depressions—elevations where the picture should print black and depressions where it should print white. As it rotates on the advancing cylinder of the transmitter, a tracer or point is rested on the surface of the film, rising and falling with the undulations, and exaggerating them by leverage so as to communicate motion to four tappets, which, as they rise and fall, send electric impulses over the line. In the receiving apparatus these impulses are communicated to a lever bearing a diamond cutter that traces on a wax film on the receiving cylinder a duplicate of the gelatin film on the transmitting cylinder. From this wax film a plate can be made for printing, the result being a line engraving, which may be made as fine as desired.

The reader will readily understand that the principles involved are such that the work is not necessarily confined to reproductions for the printing-press. Ornamental designs upon gold and silverware may be copied automatically, and monograms, etc., duplicated indefinitely with this apparatus. The largest field is for illustrative pur-

poses, and it is thought that it will stimulate the use of news illustrations in the daily press. Events taking place in London or Paris can be illustrated in the papers of the United States with the same facility as if occurring in the city where the paper is printed. Indeed, the difference in time between the cities of the two continents would often result in pictorial representation here before the same can appear in the pages of the local press over there.

It has been suggested that this invention would be an aid to the police, as furnishing quick means for sending the portrait of a criminal all over the country when he is wanted for some crime. As a matter of fact, however, the detectives depend much more upon descriptions than photographs for identifying a criminal. The uselessness of the photograph in this connection is illustrated by an English sheriff's experience. A certain criminal was wanted, a reward having been offered for his capture. He possessed six different photographs of the man, and had them reproduced in large numbers and sent to the local police all over Great Britain, together with a description and a copy of the offer of reward. Two days later he received a telegram from the efficient head of police in a small town: "The gang located. We have five of the men wanted under lock and key, and every prospect of securing the sixth before night."

Messrs. Rogers and Amstutz have opened to the world a new telegraph and a new picture-gallery. Let us hope that the practical operation of their inventions will be as rich in performance as they are in promise.

ELECTRICITY DIRECT FROM COAL.

A Problem which Edison and Others have sought to solve—The Key may yet be found.

THE thoughtful attention of many investigators has been given to the great problem of converting the potential energy of coal directly into electrical energy, without the wasteful intervention of the steam-engine, and, though the solution still evades the profoundest thinkers, so much light has been thrown upon the subject by various experimenters that at the present time we know much more about the conditions that govern success or failure than we did a few years ago.

Electricians have known for a long time that heat could be turned directly into electricity by means of the thermo-electric couple, but that electricity could be thus produced economically has never been suspected. Indeed, it is a most expensive way of producing a very minute current. Nevertheless, a recent inventor claims to have developed a practical motor on this principle that will produce more electricity per pound of coal burned than is now obtainable through the medium of the steam-engine.

The metals vary in conductivity. Silver is the best conductor among them, and lead is one of the poorest. If we join a bar of silver and a bar of lead and alternately heat and cool the junction, an electric current will be set up in a wire connecting the opposite ends of the bars. This current is so trifling as to equal only the one-hundredth of a volt at a temperature of 530° C. The Clamond generator is a philosphical toy constructed on this principle. It consists of the arrangement in superposed rings of pieces of metal alloys that have been found to produce the greatest

currents. These rings are insulated by asbestos and heated in the centre by a gas-flame, while the outer ends are cooled by radiation. The alloys of metals have peculiar and unexpected qualities, often widely different from what the component metals possess alone. It has, therefore, been an interesting study with some to try new alloys in the hope of finding a combination that should set up a current of reasonable force.

Some twelve years ago, Mr. Edison gave much attention to the solution of the problem by means of thermo-electricity, designing a generator in which he sought to attain the desired end by apparatus of highly ingenious construction. The operative feature was the magnetization and demagnetization of iron by rapid alternations of temperature. These alternations of magnetic intensity were utilized to generate induced currents in surrounding coils. This idea, which appeared promising at first sight, never went further than an experimental machine that was not satisfactory except in strengthening the opinion of electricians that a large efficiency could never be hoped for from any thermo-electric generator.

Very recently, however, announcement has been made in the newspapers that a Hartford inventor was trying to improve upon Clamond's apparatus, having been experimenting with alloys in the hope that he might discover some of such widely different conductivity as to render a thermo-electric generator a useful and cheap means of securing the electric current direct from the coal. He now claims to have discovered suitable alloys, and to have perfected a generator for putting the same into practical use. He will have to make a public demonstration of these things before he gains credence from the scientific world. He is understood to form his alloys into wedges, which are

combined in ring-form, pains being taken to avoid well-defined junctions and to merge one alloy gradually with the other where the wedges meet. Several of these rings are formed, one above the other, as in the Clamond generator, being separated by sheets of asbestos. The central cylinder, through which the heat is applied to the inner ends of the couples, is lined with a fire-proof plastic cement, and the cooling of the outer ends is accomplished by means of a circulating current of cold water. A common coal-stove furnishes the heat, and the electricity is carried off by two wires, as from a dynamo. Further information as to the development of this interesting apparatus will be awaited with interest.

Efforts are also being made to solve the problem from the chemical side. The correlation between chemical and electrical energy is a well-established fact, and in the case of many substances, such as carbon, is capable of being expressed quantitatively, and with as great accuracy as the relation between heat and mechanical force, which finds its mathematical expression in the figures expressing the mechanical equivalent of heat. In the ordinary voltaic cell, which we see in batteries for house use, as in ringing door-bells, the electric energy developed is derived from the direct conversion of the energy of chemical combination, and the quantity of the one which it is possible to realize from an electrolytic cell of any predetermined constituents may be calculated with the same accuracy in terms of the other, as the possible mechanical energy which can be developed from the combustion of a ton of coal.

Dr. W. Borchers, of Duisburg, Germany, has attacked this problem and sought to solve it by chemistry, his line of research involving the construction of a voltaic cell in which the cold combustion of carbon can be effected with

the hope of obtaining an efficiency approximating nearly to that which theory indicates. It is stated that the learned doctor has been so far successful as to obtain twenty-seven per cent. of the energy of combustion of the fuel in the form of electrical energy. The fuel used was not coal, but the result obtained is none the less remarkable. When we consider that only about fifteen per cent. of the energy stored in the coal is now obtained in the dynamo by the medium of the steam-engine, Dr. Borchers's success is the more marked, and, as this is the result of his first experimentation on these lines, we may reasonably hope for further efficiency as the problem is studied more understandingly. Dr. Borchers has communicated the result of his experiments in a paper read before the German Electro-Chemical Society, and announces the conclusion that the problem of the cold combustion of the gaseous products of coal and oil, in a gas battery, and its direct conversion into electrical energy can certainly be accomplished. Considering how many intelligent brains are struggling with this problem, and the success already attained, it seems not too much to prophesy a triumph early in the coming century.

NIKOLA TESLA AND HIS OSCILLATOR.

A Wonderful Electric Machine devised by a Wonderful Engineer, who bids us throw all the Steam-Engines in the Scrap-Heap.

NIKOLA TESLA, the engineer who came from Europe some ten or a dozen years ago to beg a place in Edison's workshop, has proved himself a fit pupil of the Wizard of Menlo Park, and capable of standing with him as his

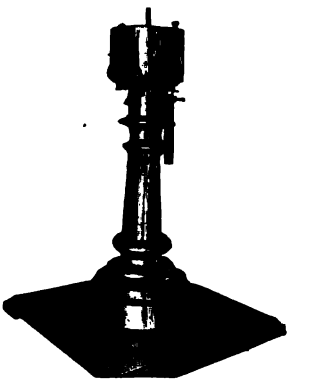
peer. In his oscillator we have the promise of an invention as great as any of Professor Edison's—an invention that is liable to turn a third of the machinery of the globe into old metal fit but for the scrap-heap. He has harnessed a steam-cylinder to the core of a dynamo, and released the intervening mechanism from further service. Steam-engines of all sorts, locomotives, dynamos, electric motors—all these, as at present made, will be useless when Tesla's oscillator comes into general use. It may solve the problem of knocking a couple of days off the time required to cross the Atlantic, and it will save our coal so that we can make one pound do almost the work that was done by two pounds. For conferring this boon upon the world, Tesla deserves the thanks of a grateful race.

The personality of the man is as interesting as his work. He looks like a young overworked Slav, and that is what he is; but he writes and speaks like a poet—with this difference, that his visions are real, that he dreams of that which is possible of accomplishment, of mechanical and scientific projects which he will put into being, if his days are sufficiently long. No one who knows him expects that Nikola Tesla will stop inventing when he has completed the oscillator. Already his mind is set on a score of other problems as useful in their solution as the one that is likely to be settled by the machine with which we are now specially interested. He suggests that in the not distant future he may be able to give us light at a small fraction of present cost, and to transmit electric intelligence without wires or other artificial media.

The oscillator has been made in several forms, Mr. Tesla preferring to perfect it before seeking to introduce it generally. That shown in the illustration is the one that was exhibited at the World's Columbian Exposition in

Chicago. It is merely a steam-chest, disassociated from the usual governing mechanism, and so simply and accurately made that it is run at a pressure of three hundred and fifty pounds (double the pressure practical in high-grade high-pressure steam-engines), without any packing, this steam-chest being joined with an electro-magnetic coil into whose fields of force it thrusts, reciprocatively, armatures carried by its pistons. The regulation is accomplished by the electric currents thus set up. The machine used in Tesla's laboratory, which was destroyed by fire early in 1895, was used to run sixty incandescent lights. Mr. Tesla was about to give his invention to the world when the fire occurred, which delayed the introduction of his wonderful machine.

FIG. 40.



TESLA'S OSCILLATOR AS SHOWN AT THE COLUMBIAN EXPOSITION.

The latest form of his invention might be called a double machine. It is made horizontal, not vertical as shown in the illustration, and is all arranged on one base. There are two electro-magnetic generating systems, which correspond to dynamos, and one small steam-chest. There are two pistons, which are vibrated by the steam eighty to a hundred times a second, or more rapidly than the eye can follow them. Each piston bears an armature which is plunged at every stroke into the field of the magnets. The pistons are arranged to move in opposite phase, but could be changed to any phase. On top of the steam-chest is an extra miniature oscillator, designed to control

the admission of steam and make the vibration of the engine independent of the load. There was never any leakage of steam from this oscillator, notwithstanding the absence of packing. In a short time another machine of this perfected type will be completed and offered to the public.

It has been calculated that the oscillator will save about eighteen per cent. of friction, as existing in the average steam-engine, besides ten per cent. of belt friction, as wasted by the indirect connection of engines and dynamos, and thirty-two per cent. of waste of energy which occurs in the ordinary form of dynamo—a total of fifty per cent. In addition, we have the advantage of a machine with so few parts that wear is reduced to a minimum, and so automatically self-regulating as to require the least possible attention. Engineers generally are agreed that these things are to be expected of Tesla's oscillator. It is designed to convert steam into electric energy by as direct a process as possible, and to that end dispenses with rotary motion in the fields of the magnets, which is not essential. In fact, some of the early forms of dynamos generated electricity by a reciprocating and not a rotary motion. It is primarily designed for use in electric lighting plants, and will find a place next in power-houses and later probably in steamboat propulsion and electric locomotives. It should cheapen power so that electrical plants will sell it at greatly reduced rates, causing an immense increase in the use of electrical power and doing away with stationary engines of all sorts.

Concerning what he may give us in the future, Tesla has this to say:

"Every thinker, when considering the barbarous methods employed, the deplorable losses incurred in our best system

of light production, must have asked himself, What is likely to be the light of the future? Is it to be an incandescent solid, as in the present lamp, or an incandescent gas, or a phosphorescent body, or something like a burner, but incomparably more efficient? . . . Alternate currents, especially of high frequencies, pass with astonishing freedom through even slightly rarefied gases. To reach a number of miles into space requires the overcoming of difficulties of a merely mechanical nature. There is no doubt that, with the enormous potentials obtainable by the use of high frequencies and oil insulation, luminous discharges might be passed through many miles of rarefied air, and that, by thus directing the energy of many hundreds of thousands of horse-power, motors or lamps might be operated at considerable distances from the stationary sources."

THE ELECTRIC LOCOMOTIVE.

A Number actually in Use, and Others being developed—They may in Time crowd out the Steam-Locomotive.

ABOUT 1887 or 1888, when electricity came to be accepted as the motive power of the future, many persons expected to see the steam-engine driven out of use. Gradually they learned that the dynamo was not a source of power, but that a steam-engine, water-wheel, or something of the sort was required to furnish power, which a dynamo or generator would convert into electricity and transmit along a wire, from which it might be taken again and used through an electric motor. Therefore the steam-engine is still with us, and likely to remain. For similar reasons the steam-locomotive has continued in use while

electric roads have developed all over the world, and only within a very short period has the downfall of the "iron horse" been predicted. Truth compels the admission that the latter has not been greatly improved since the days of Stephenson. True, locomotives are vastly bigger, stronger, and faster now than they were then. Still they are very wasteful machines. While perfected stationary engines develop as much as eighty-five per cent. of efficiency, the locomotive, owing to forced speed, eats up coal in a manner perfectly regardless of dividends to stockholders, and with but little disposition to assist in settling interest due bondholders.

It has been and is the endeavor of inventors of electric locomotives to develop a machine that would be more economical than the steam-locomotive, and perhaps exhibit more speed, though locomotives as now built will run faster than railroad managers care to have them, owing to the frightful results to be anticipated from accidents at high speeds.

Professor C. C. Page, of the Smithsonian Institution, was among the first experimenters with the electric locomotive. He designed one in which a fly-wheel was driven by a piston-rod "sucked" back and forth between two hollow cylindrical magnets. In 1851 he mounted this motor on wheels, and furnished it with electricity from batteries of the type now used to ring electric door-bells, though much larger. On this locomotive he succeeded in travelling from Washington to Baltimore, but found that the jarring prevented the successful operation of the batteries. His best speed was a mile in about three minutes on a favorable grade.

In 1879, Dr. Siemens exhibited an electric locomotive at Berlin. It was regarded simply as a novelty.

In 1880, Professor Thomas A. Edison experimented with an electric locomotive at Menlo Park, New Jersey. This was improved by Stephen D. Field, and in 1883 Edison and Field exhibited an electric railroad at the Chicago Railway Exposition, using a three-foot gauge and three-wired rails. Their locomotive consisted of an electric motor mounted on a carriage, and operating the driving-wheels by means of a connecting belt and pulleys. They were able to show a speed of twelve miles an hour on a circular track of fifteen hundred and fifty-three feet.

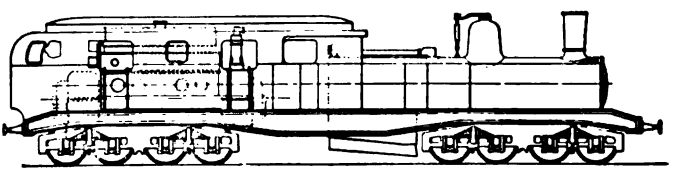
Leo Daft, about 1883, exhibited an electric locomotive at Saratoga. With a two-ton motor he succeeded in pulling an ordinary passenger-car with sixty-eight persons at a speed of eight miles an hour on a route that was not favorable as to grades and curves. Mr. Daft subsequently built several exhibition roads that attracted much attention to his locomotive. It was tried for commercial purposes on a street railway in Baltimore in 1885, but was afterwards abandoned in favor of the trolley. Both the Edison-Field and the Daft locomotives were tried on the elevated railroads of New York City, but failed to supplant the steam-locomotives.

The Thomson-Houston and other companies introduced small electric locomotives about 1891 for haulage in mines. They operate by overhead trolleys, and have a moderate sale.

The J. J. Heilmann electric locomotive is being tried in France the present year (1895), and gives great promise of success. It is really an electric power plant on wheels. Instead of producing the electric energy at a station, and sending it out by overhead wires to the cars, the entire mechanism is carried as a locomotive. The first one built was of small power (six hundred horse-), though fifty feet

in length. As will be seen from the illustration, there are sixteen wheels, bearing a platform of steel girders. The smoke-stack is at the rear end, strange to say, the cab with its pointed end being forward. The steam-engine and boiler are much like those of any steam-locomotive. They

FIG. 41.



THE HEILMANN ELECTRIC LOCOMOTIVE.

are of the Brown type, and as well made as it is possible to build a modern compound condensing engine, and, being directly connected with the large dynamo, which occupies the greater portion of the cab, there can be no lost power from friction between the two machines. A switchboard stands in front of the driver, with controlling levers on either hand. Each of the axles bears a rotary electric motor, so that all of the wheels are drivers, presenting less chance of slipping on the track than with the ordinary steam-locomotive, part of whose weight rests on truck-wheels. As each axle of the Heilmann locomotive is independent, there is no difficulty in turning short curves at good speed. The cars to be drawn by this locomotive may also bear electric motors on the axles, to which the current will be conveyed by wires from the dynamo on the locomotive.

The total weight of this locomotive is one hundred and fourteen long tons, and the tests show a draw-bar pull of

fifty thousand pounds, which is enough to pull a two-hundred-ton train at a high speed.

The principle of this electric locomotive of Heilmann's seems preposterous at first thought. People say, If he must use a steam-engine, why bother with converting the power into electric energy and then conveying it to the wheels? Why not dispense with the dynamo and motors, and couple the engine directly to the drivers, as in the ordinary locomotive? This reasoning is not correct, however. The utilization of the dynamo and motors saves more coal than it costs to carry their added weight or than is lost by their friction. There is an economy of time during which the fires have to be run, because greater speed is obtainable without forcing. The saving in jar and friction by dispensing with the heavy reciprocating parts is very great. Anyway, the Compagnie de l'Ouest, on whose lines this locomotive was tried, were so well satisfied with the tests that they have agreed to rent two larger locomotives of the same pattern. These are now building, and will be on a much larger scale. Each is to be of fifteen hundred horse-power, and capable of hauling a two-hundred-and-fifty-ton train at a speed of sixty-two miles an hour. Their operation is looked forward to with interest by railroad men the world over. Their cost is estimated at about thirty thousand dollars each, or about three times that of an average steam-locomotive.

The Sprague electric locomotive, shown in the illustration, was built at the Baldwin Locomotive Works, in Philadelphia, after designs by Messrs. Sprague, Duncan, and Hutchinson, and was completed in 1895. The North American Company are to use it in hauling heavy freight and in switching. There are four pairs of drivers coupled together by quarter-cranked connecting-rods. The weight

is one hundred and thirty-four thousand pounds, equally distributed between the fifty-six-inch drivers. It is designed for a speed of thirty-five miles an hour. The draw-bar pull exceeds ten thousand pounds, each of the four

FIG. 42.

THE SPRAGUE ELECTRIC LOCOMOTIVE.

motors being of about two hundred and fifty horse-power. The brackets which carry the motors are pedestal boxes of peculiar form made of cast steel, the lower sides being arranged to be dropped out. These boxes carry both the axles upon which the armatures are rigidly mounted, the field magnets being concentric to them. The motors are iron-clad, the field magnets consisting of two steel castings, having two field coils placed at the ends of the motors, forming two consequent and two salient poles. Compound-wound magnets are used, and slotted Westinghouse armatures. The whole structure is carried on equalizing springs. The controlling apparatus in the cab is so arranged that the engineer sits at the right-hand side looking forward, no matter which way he is running, for the locomotive is a double ender.

E. Moody Boynton, of West Newbury, Massachusetts,

whose bicycle railway has attracted much attention within a few years, is now experimenting with an electric locomotive for the same. He uses upper and lower rails, guide-wheels engaging the upper rail. The driver has removable web plates fastened to hubs rotating loose on a shaft situated in the frame. The armature and field magnets are between these web plates, one element fast to the wheel-tire and the other to the shaft.

The General Electric Company of New York are now placing an electric locomotive on the market, intended for use in drawing heavy trains. It operates on the trolley principle, receiving the current from an overhead conductor. One of thirty tons and another of forty tons have been completed, and these are in use in railroad yards as switch-engines.

But the triumph of the electric locomotive is best demonstrated by the ninety-five-ton locomotive just placed (1895) by this company with the Baltimore and Ohio road for use in the Belt Line tunnel, and built for a speed of fifty miles an hour. It is about thirty feet long, and stands very high. The cab rests on two enormous trucks, having four wheels, each of sixty-two inches diameter. The axle of each pair of wheels is in the centre of the armature of a motor, so that the construction is very much like that of an electric motor set to run upon a pair of fly-wheels. The motors are six-pole, gearless, and are flexibly supported upon the trucks, transmitting their motion from the armatures to the wheels by means of an especially designed flexible coupling. The method of spring suspension has been carefully modified to allow of the immediate adjustment of the wheels to the irregularities of the tracks, thus effecting a diminution in the wear both of the motors and tracks. The massive armatures are of the iron-clad

type. A hollow shaft serves to carry each armature, and through this passes the wheel-axle, to which it is connected by a universal coupling that allows freedom of movement

FIG. 43.

THE BALTIMORE AND OHIO ELECTRIC LOCOMOTIVE.

in any direction. The motors are the largest ever used in railroad service.

The cab is spring-supported on the truck, and is built of sheet iron and wood, having windows on all sides, so that the occupants have an unobstructed view. Within the cab is set up the series parallel-controller, by means of which the movements of the locomotive will be at the command of the driver, as also the air-pumps, operated by

a small electric motor, to supply air to the brakes and the whistle.

The overhead arrangement is of the trolley type, yet the trolley or wheel is entirely dispensed with. Fixed above the track in the tunnel is a broad, grooved band of metal, through whose length a slider may run. This slider is connected by a pole with the locomotive. The grooved metal is the conductor that carries the current, which is too powerful for an ordinary wire, and the slider takes the place of the trolley-wheel, whose rolling contact is insufficient to carry the strong current. This locomotive is also equipped with bells, safety devices, etc., and has a Janney automatic coupler at each end. This is undoubtedly a thoroughly efficient electric locomotive, calculated to handle as heavy trains as any steam-locomotive. It remains to be seen whether it will stand the test of time.

The electric locomotive has a slight advantage over the steam-locomotive in that it will start a greater load, the pull being constant throughout the entire revolution of the wheel, the difficulty of variation in pull caused by the dead-centre of the steam-locomotive being avoided. The other advantages are: a considerable economy in coal, reduction of the hammering and side-strains to the track, probable less cost of repairs, and the practicability of using the electric locomotive several more hours daily than the steam-locomotive. These considerations lead many to ask whether the days of the steam-horse are not numbered. Already their manufacture has seriously decreased, owing to electric roads taking business from steam-roads. Mechanics are agreed that they cannot be materially improved, while the electric locomotive, being so recent, is likely to do much better in the future.

It remains to be seen which type will develop fastest, the Heilmann, large and cumbrous, but self-contained, or the General Electric Co.'s or the somewhat similar Sprague type, compact and mighty, but operating from a power-house by means of an overhead conductor. The Boynton locomotive will not be a competitor with either, being designed for light railways only. It seems best adapted for pleasure railways at sea-side resorts.

LIGHT-TRAFFIC RAILWAY SYSTEMS.

Transportation by the Electric Trolley, Steam, Compressed Air, Coal Gas, or Ammonia, over Elevated, Surface, or Underground Roads.

It is asserted, apparently with truth, that the street-railways of the United States now carry more passengers than the great steam-railways connecting the cities of the country. By the name street-railway is designated all those means of traffic in and about large cities and towns, and classed as trolley roads, elevated roads, rapid transit, or underground roads, etc. Some years ago the capital of the country was directed towards the construction of long lines of railway across uninhabited territory, and it is because of this fact that we lead the world in railway mileage. Only within a few years has it dawned upon the people who sunk their money in those roads for developing the far West that the best place to build railroads was right in large cities, where there were plenty of people to ride on them.

Though it must be admitted that the American capitalist has been slow in appreciating the value of city railways,

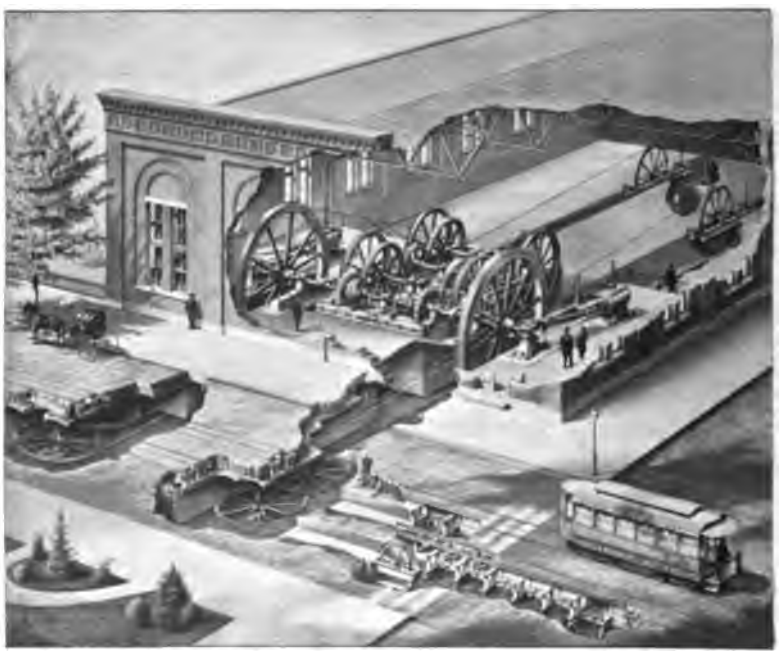
he is now thorougly convinced of their value, and it is comparatively easy to capitalize any street-railway for which a franchise can be obtained. There are now about twelve thousand miles of street-railways in the United States and Canada, nearly half of them still using horse-power, while the remainder are operated by electricity, steam-motors, and cables, in the order named.

New York City uses or has tried about all the systems in vogue, and exhibits a preference for the elevated steam-railroad. When these elevated roads were first talked of, it was proposed to build them with drawbridges about a mile apart, for the convenience of teams or wagons of unusual height desiring to pass below. This reckless proposition for the convenience of those below was never carried out. In 1868 the first road—constituting what is now the lower part of the Ninth Avenue road—was built. Many thought that cars run on a track supported on a single row of iron posts could not be safe, and for this and other reasons the traffic on the road was small for some years. During the first two years endless cables were used for drawing the cars, but later were abandoned for small steam-locomotives, the Forney engines being the type used to-day. In time the New York public came to like the elevated cars, and the Ninth Avenue road was several times extended. In 1878 the Sixth Avenue and Third Avenue elevated roads were opened, and in 1887 the Second Avenue. These roads now carry nearly half a million people twice a day—that is to say, they bring that number of people to business every week-day morning and carry them back at night. They maintain thirty-six miles of double-track road, which cost a total of thirty-five million dollars.

New York also maintains cable-roads on One Hundred and Twenty-fifth Street, Broadway, and on Third Avenue.

It is thought that these lines will substitute an electric wire in the conduit for the cable in the near future, that system having been much perfected within a few years.

FIG. 44.



CABLE-DRIVING PLANT, AS DESIGNED BY ROBERT POOLE & SON.

In fact, a successful conduit-electric system has been in operation in Buda-Pesth since 1889, being built on the plans of Siemens and Halske. Americans seem not to have been so successful, but they can now profit by copying the good points of the Hungarian line. For further information on this point see the chapter on conduit railways. The other lines of New York City are operated by

horses, though it is rumored that one or more of them will change to the storage-battery in the near future.

The combined means of transit above described being inadequate to meet the demands of the travelling public, it is now proposed to build a system of underground roads, and two routes are projected with every prospect of being built in the near future. The motive power has not as yet been decided upon, but it is thought that the electric locomotive will be chosen.

Chicago has three elevated railways. They are not as popular there as in New York, the surface roads carrying nine-tenths of the traffic; but as all three are of recent construction, no doubt their traffic will increase as the public become habituated to their use. The last of these roads is not yet (1895) in running order. It is to be equipped with electric motive-power, one motor-car drawing a short train, according to the demand. It is thought that this will be cheaper than using steam-locomotives, and the annoyance from smoke will be avoided. They also have cable-roads whose tracks have a mileage of 34.77. These carried one-fourth of the traffic in 1894.

The street-railways of Philadelphia carry one hundred and seventy-five million passengers annually. The trolley is the most favored means of propulsion, though the cable was used first, and taught the public the value of rapid transit. The reduced expenses of the trolley system caused the cables to be superseded thereby in 1895. The trolley roads have caused a fearful record of deaths, killing a number of hapless pedestrians every month and injuring many more.

Brooklyn's record of killed and maimed by trolley accidents is equal to that of Philadelphia. In two years' time a hundred deaths and five hundred personal injuries were

reported. Nearly all the surface lines of the city are operated by the trolley system. There are twenty-six and a half miles of elevated roads, constructed in a manner very similar to those in New York. The combined street-railway travel of the city is about three hundred thousand passengers daily.

In Boston trolley roads are used, the cars being quite large for street-cars. A subway for electric cars is also being constructed at the Hub. In San Francisco the cable-road is used. In most of the minor cities of the country the trolley roads prevail.

London's underground railway has been much written about. The passengers ascend and descend at the stations by means of elevators, a method that would add to the comfort of American elevated roads. The fare is four cents. There are two companies operating underground lines, and they carry over three hundred million passengers annually, while the omnibuses and suburban steam railways carry about twice that number.

The street-railways of Paris employ steam, horse flesh, and compressed air as motive powers on the surface, and the storage-battery on the underground line. These batteries are carried on a sort of tender which supplies the motors of the cars, which are coupled up as short trains. The total transportation is about one million persons daily.

In Berlin the horse-car lines are arranged to radiate from the centre of the city. The Berliners ride less than the Parisians, their roads carrying one hundred and twenty million persons a year. The universal fare in Germany is ten pfennigs, or a trifle over two cents. A number of electric roads are being built throughout the country, the extent of trackage at the close of 1894 being one hundred and eighty miles, with six hundred and thirty

cars, and power stations of a total horse-power of eight thousand.

The light-traffic railways of the United States have been cutting into the local patronage of the trunk lines seriously by paralleling them for considerable distances. A nearly complete trolley line now extends between New York and Philadelphia; the New York, New Haven and Hartford Railroad has been a sufferer in Connecticut; the suburban cities around Boston present a perfect net-work of electric roads; while lines are now projected to connect Philadelphia and Harrisburg, Baltimore and Washington, Chicago and Milwaukee.

Of the various methods of railway building for street lines, the underground or tunnel system is the most costly, the equipment involving an expense of from three to five million dollars per mile. The elevated or overhead system comes next, with a cost of from one-half to three-quarters of a million dollars per mile. Then cable railways, with a charge of three hundred and fifty thousand dollars per mile. Probably the electric conduit system, which is described in another chapter, may involve an expenditure of one hundred and seventy-five thousand dollars per mile. Next in first cost is the horse-railway, which will average close to seventy-five thousand dollars a mile for equipment. The electric trolley outfit only involves a cost of forty-five thousand dollars a mile. The storage-battery and compressed-air systems are said to be even lower in first cost. The cheapest for ordinary use is undoubtedly the trolley, as is evidenced by its general adoption. Under special circumstances, any one of the other systems may be preferred.

The trolley system is too well known to require any description here. In a few places, as Cincinnati, what is

called the double trolley system is used. In this there are two overhead exposed conducting wires and two trolley-poles on each car. The extra wire is for direct return of the current instead of employing ground connections. This system avoids interference with underground pipes, which sometimes suffer from electrolysis because of the grounding of the current from the single trolley wires; but it cumbers up the streets badly, and at corners, where double tracks cross, the whole crossing is covered with a net-work of exposed trolley wires, which is unsightly and somewhat dangerous.

A combination of the electric and cable systems is in use on a most interesting road at Stanserhorn, near Lucerne, Switzerland. This is a mountain railway, over three miles in length, ascending to a hotel at an elevation of six thousand two hundred and thirty-three feet, almost at the peak of the mountain. The road is built in three sections, the grade of the highest section being sixty per cent. of forty-five degrees. So far as known, this is the only mountain road in which a continuous cogged rail or rack is dispensed with. The cars depend entirely upon the grip upon the cable and upon automatic brakes for gripping the track for their safety. At the ordinary speed the brakes will stop a loaded car within one-third of its length. There has never been any hitch or accident in the operation of the road since it was built, in 1893. On each of the three sections is an electric motor-house, where are located two motors, each of sixty horse-power, one for use, the other for a reserve. These motor-houses derive their power by feeder-wires from a power-station several miles away, at Buochs, where the river Aa has a fall. This same power-house supplies another railway and sells power for local uses. The Stanserhorn Railway only pays one hundred

francs (twenty dollars) per horse-power per annum, and, as it buys only one hundred and fifty horse-power, its annual bill for power is only three thousand dollars. Six cars are operated during busy seasons, and each car seats thirty-two passengers, weighing, with that load, a little less than seven tons. Each car carries electric signalling-rods, and all the stations are telephonically connected. The cable is made of crucible steel, with a hemp core to facilitate bending. Its diameter is an inch and one-third on the steepest section, and its tensile strength sixty tons. This road cost only three hundred thousand dollars, notwithstanding it is built over most difficult ground, a part of the route requiring to be tunnelled through a loose mass of fallen boulders.

Another interesting mountain railway is that at Pike's Peak, completed in 1891. It is constructed on the Abt system, having a rack or double-cogged rail made of parallel bars in which the openings are staggered—that is, arranged with a tooth always back of a space—and, there being two cog-wheels meshing with the rack, it is almost impossible for an accident to happen, which would throw all out of gear at once. The power of the locomotive is applied to these cog-wheels under a reduction of speed, the grade being twenty-five per cent. in places. The road is eight and three-quarters miles long, and attains an altitude of fourteen thousand two hundred feet.

The steepest mountain railway in the world is that projected at the Jungfrau in the Alps. Its grade is within two per cent. of forty-five degrees, and its construction resembles that of a lengthy elevator. It is to be a cable-road, the whole line being within a tunnel, and the cars are to be so shaped that they exactly fill the circular hole made by the rings of the tunnel. Then, by introducing a

powerful air-tight door at the lower end, all serious danger of accident due to a breakage is avoided, for if a car falls back it is cushioned by the air behind so that it comes to the foot at a very gentle speed.

The hydraulic sliding-railway system has attracted interest at various times because of its novelty, but no one with capital has been sufficiently convinced of its practicability to put a line in operation for general use, though an experimental line has been built in London. The peculiarity of the system is that it makes use of runners instead of wheels for the cars, operating on the principle of a sleigh. These runners are broad iron shoes, shaped like the face of the rail on which they rest. The sliding surface is obtained by forcing water at a high pressure through small orifices in the soles of the shoes, or runners, so that the escaping water actually lifts the runner and allows it to glide on a very thin surface of water. The experiments demonstrate that with a perfect track on a level the friction is very much less than with wheels, and a speed of one hundred and twenty-five miles an hour, with an enormous saving of coal, has been theoretically demonstrated as possible. The propelling power is also furnished by water, there being water-jets placed between the rails so that they can be automatically opened and closed by the train itself. These jets impinge on pallets located under the cars, much as water strikes against a water-wheel. As the railway involves neither locomotives nor wheels of any sort, it involves a very large saving in one direction. It is apparent, however, that it would be very wasteful of water, and the cheapness with which this could be obtained would be an important element to consider in its construction. Possibly such a road, drawing upon the Niagara supply, might be made to pay if the route were level. On heavy grades

the system could scarcely be expected to give satisfaction.

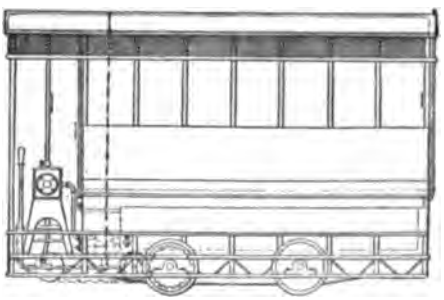
The mechanism of a cable-road is shown by the illustration used as a frontispiece, representing a design built by Robert Poole & Son Company, of Baltimore, Maryland. San Francisco was the first city to adopt this equipment, Chicago following. When the first Philadelphia cable-road was built, it was thought that several hundred thousand dollars could be saved by constructing the casing of the conduit of comparatively thin sheet-iron. This was used, and did very well until the frost began to work in the ground, when the sheet-iron was warped out of shape, and had to be taken out and thrown into the scrap-heap, heavy castings being substituted. A cable-car, with its arrangement of grips, costs a little more than the trolley-car, but the running expenses are not materially greater, so that where exposed wires have been objected to the cable-road has proved a boon.

Some information regarding the storage-battery system of operating cars will be found in the chapter on "The Storage-Battery," and the compressed-air system is also referred to in the chapter on "Compressed-Air Mechanisms."

Ammonia-motors and gas-motors have received some attention as affording desirable means of power for street-cars. As ammonia vaporizes at a very low temperature, it has been particularly attractive to experimenters searching for a better expansive medium than steam. At the recent Chicago Exposition the world was made acquainted with a promising form of ammonia-motor, devised by a Mr. MacMahon. He has developed a means of securing highly purified anhydrous ammonia, and of preserving the exhaust vapor, which, in the case of a

steam-engine, is allowed to escape. The ammonia being used over and over, the only cost of operation is the coal

FIG. 45.



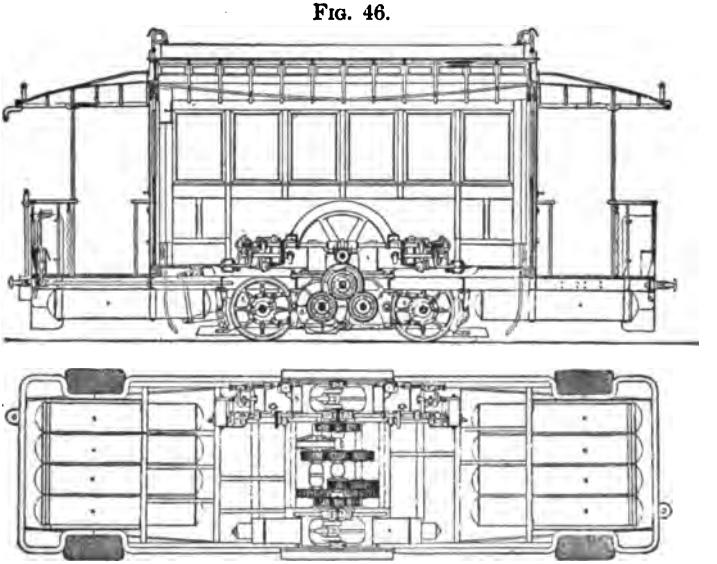
AMMONIA-MOTOR APPLIED TO STREET CAR.

burned. Under somewhat unfavorable conditions, Mr. MacMahon was able to drive his motor-car at a speed of fifteen miles an hour, with a coal consumption of only two cents a mile. This showing was so favorable that more may be expected of the ammonia-motor in the future.

The compressed-gas system of car-propulsion offers the same general advantages that are claimed for the storage-battery and compressed air systems—viz., absence of smoke, dirt, wires, and noise. There are two systems of gas motor-power before the public, both European—the Guillieron and Amrein, and the Luhrig systems. The latter is shown in the illustration. Twin engines are placed on each side of the car, under the seats, which run lengthwise. Fourteen horse-power is required for a car seating sixteen persons. In the roof are cold-water reservoirs, while the gas reservoirs *a* are under the front and rear platforms. The speed can be altered by means of a pedal under the foot of the motorman. He also operates hand-levers to throw the motors in or out of gear in stopping and starting the car.

The compressed gas is delivered by regulators to the motor-cylinders *b*, of which there are four, so that one may always

FIG. 46.



LUHRIG COMPRESSED-GAS MOTOR.

be in action upon the driving-shaft *c* (for gas-engines only give out power every fourth stroke). The gas is admitted to the cylinders, mixed with a certain quantity of air, and ignited, causing an expansion or small explosion of gas, which does the work. *d* is the driving-gear for connecting the driving-shaft with the driving-axles *e*. The car illustrated and described weighs seven and a half tons, but the maker reports that he has succeeded in reducing the weight to four and a half tons, or about the same as a trolley-car of the same capacity. The small car, which has but a single motor, consumes thirty-five feet of gas per car-mile, and the large one forty-two feet. The cylinders of the

large car contain ninety cubic feet of gas compressed to eight atmospheres, so that the capacity should run the car about seventeen miles. The cost of fitting up a charging-station is stated to be three thousand dollars. If in practice there arise no unforeseen objections to this system, it appears likely that American gas companies will seek to introduce it here in order to increase their sales.

While electricity undoubtedly has the call against all other systems of railway power, yet we may expect to see various other motors used from time to time as being especially suited to some particular form of transportation.

CONDUIT ELECTRIC RAILWAYS.

The Coming Substitute for the Deadly Trolley—Various Plans, Some of them Successful, for placing the Wires Underground.

THE hue and cry against the overhead trolley railways, because of the annoyance and unsightliness of their poles and wires, and the nuisance of exposing bare wires in the streets, and also because of the number of persons who have been killed and maimed by being run down, has caused the public mind to become turned towards other forms of electric traction for light railways. It is true that the trolley in itself is not responsible for the many accidents that have been laid at its door. Any other system of propulsion, operated at a like speed, without proper fenders, and by workmen often uneducated and always overworked, would have been equally destructive to life. The fault has not been with the trolley, but with the methods of operating trolley roads.

Nevertheless, some other system, doing away with overhead wires, is going to come into use, and very many are looking to the conduit electric system, with its underground conductors, to solve the problem. The fiat has gone forth in many large cities that electric wires of all sorts shall go underground, and practice in methods of properly insulating them for underground service has given experience that is useful to projectors of conduit railway systems.

One of the necessities of the conduit system appears to be a low voltage—not more than three hundred being considered desirable. This involves more expense in constructing plants and stations, but is compensated for by a great saving in leakage. The success of a conduit railway appears to be dependent more upon care and excellence of construction and moderate climate than upon any special form that has been tried. It will always be more costly of installation than the exposed wire system of the trolley, but when once generally introduced such first cost should be so reduced as not to prove prohibitive. In any case, when once it is known that the system is feasible, city governments will begin to force corporations to put the wires below ground.

The many advantages apparent from using a conduit system of electric railway propulsion are so manifest that they hardly require recording. There are no exposed wires to annoy any one, and it should prove as cheap in operation as the trolley, which has outstripped every other system and all of them combined. One of the first electric roads built (at Buda-Pesth) was on this principle, and it is often quoted as successful, yet the conditions in more northern cities are so different that projectors of roads in the United States have clung to the trolley as affording a surer success.

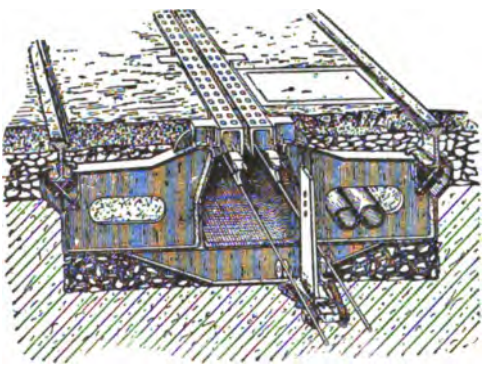
The difficulty has been from the inability to secure perfect insulation of the underground wire. Electricity has a sad habit of going off to any near-by parallel conductor, and in a conduit the ground is always near by, and always parallel, and when things are moist—which is about one-third of the time in the climate of New York—the electricity escapes at a rate that is highly expensive, and causes trouble with adjacent water- and gas-pipes, with resultant suits for damages. The open slot affords an entrance for snow and moist dirt, which discharges the electricity in a very annoying manner. It is a difficulty, however, which electricians think can be overcome, and, if some of the experimental conduit lines now being tried are satisfactory, the cable-roads of New York will shortly adopt the conduit electric system, placing electric conductors in the conduit now occupied by the cable, and passing a trolley-pole or plough instead of a grip through the slot. This will make it impossible for the cars ever to escape from control and run away, as is occasionally the case when a grip gets fast to a cable and refuses to let go its hold.

About six hundred patents have been issued in the United States for forms of conduit electric railways, which goes to show that inventors are very much alive to the demand for a suitable and practical system on this principle. The ordinary idea of such a railway is that it is necessarily a simple trolley-wire run through a slotted conduit between the tracks, connection being made with the cars by means of some form of plough passing through the slot. Our American inventors have shown that they are not hampered by any such confining conditions. Joseph Sachs has classified the conduit systems as follows:

"1. Open slot continuous conductor conduits, in which

a continuous bare conductor is placed in an open slotted trough. 2. Movable or flexible slot cover conduits, using a flexible or movable cover to protect the wires and keep

FIG. 47.



THE LOVE CONDUIT, WASHINGTON, D. C.

the slot closed. 3. Surface contact systems, in which the conductor is placed on the surface of the roadbed. 4. Sectional open slot conduits, with a sectional conductor placed in the conduit, the sections being switched in and out of connection with the main line. 5. Raised contact systems, in which the conductor is raised above the surface of the roadbed by devices on the car. 6. Induction systems, in which the car has no connection with the wire, but the current is transmitted from the supply wires to the car by induction. 7. Miscellaneous and combination systems."

The first conduit electric railway was built in Cleveland, Ohio, in 1884 (the same year that saw the birth of the first trolley road), by Messrs. Bentley & Knight, over a two-mile route. They made use of a small-sized, nearly square trough, set in the middle of the

track, and connected to the rails at distances of a few feet by U-shaped irons. Through an open slot in the top of the trough passed a plough depending from the car and rubbing against the conducting wires, which were suspended within. The motor was placed at the front of the car, connecting with the axles by cables. The undertaking did not prove a success, and was finally abandoned. Very shortly afterwards, and partly coincident with this road, a very similar system was tried in Alleghany, Pennsylvania, with a like unfortunate result.

Another form of conduit was tried later by Messrs. Bentley & Knight, on an experimental road in Boston. In this case a horseshoe trough was used, set outside the rails, and gathering the power from two wires as before by means of a dependent plough connecting the wires as it dragged along. This time the motor was geared to the axle, but the result was the same—another failure.

Other efforts at establishing conduit roads were doomed to a like fate at Denver, Colorado; San Jose, California; and Philadelphia. There are three conduit roads, however, that have been financial successes—and if three can be made to operate, why not three hundred? Buda-Pesth, Hungary; Washington, D. C.; and Blackpool, England, are the favored cities where the electric cars skim along without overhead wires. The Buda-Pesth road is the oldest, and to those experienced European electrical engineers, Siemens and Halske, is due the credit of building the first road of the sort which was a commercial success. So successful has this road proved that the original route, of one and a half miles in 1889, has been extended to seven miles and double-tracked nearly the whole distance. About fifty cars are run. The conduit is placed beneath one rail, or, more accurately, beneath a

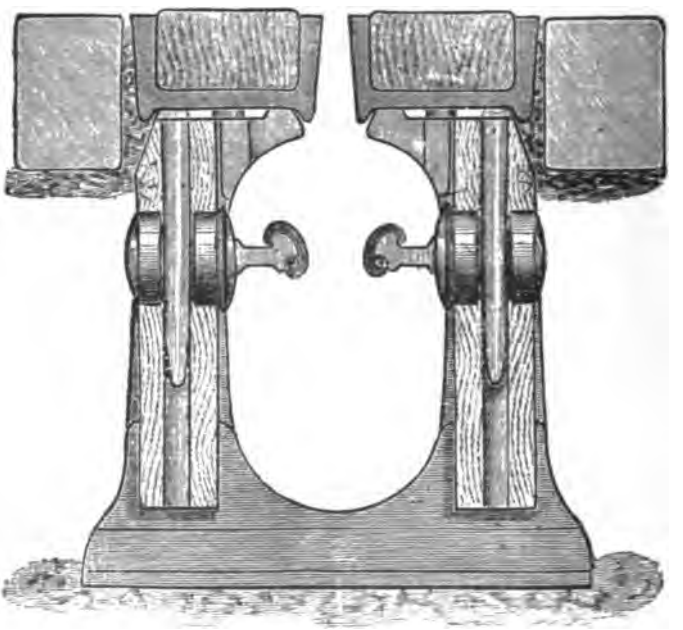
pair of rails, for the peculiarity of the arrangement is that each side-rail of the track is made of two rails lying close together. Between the pair, on one side of the track, is the open slot that admits the plough or travelling connection to the conduit. This latter is almond-shaped, and a fraction over eleven by thirteen inches in size, with a slot one and three-tenths inches wide. The conduit has concrete walls, and the drainage is excellent, so that there is no serious loss from electric leakage, which has been the death of most American conduit systems.

The Love conduit system has proved successful at Washington, D. C., having been installed in 1893 on the Rock Creek line. The route is only a mile and a half long, and the conduit is very much like that of the Broadway cable road in New York. A large casting supports at intervals the central slot and the side-tracks, together with a pair of pipes for carrying feeder-wires. Two copper wires are used to carry the current, and they are supported on mica insulators, and kept in tension by means of springs at the end of each section. The travelling-contact is mounted on a trolley carriage, running in the slot, and detachably connected with the car-truck. The conduit—which is twenty inches deep and fourteen wide—can be inspected at any point by moving one of the detachable slot-rails. There are also man-holes at distances of a hundred feet. The cars are arranged as for a trolley road—in fact, they are also used with an overhead trolley on another part of the same line.

The Smith conduit—at Blackpool, England—was completed the present year, and it is too early to say much about its success, but the management say that it is entirely satisfactory. They make use of a central conduit and slot, which is set on chairs of cast iron at distances of three

feet, the whole resting in a bed of masonry. The conduit is the smallest in use, being only six by ten inches. The sides are of wood and the slot-rails of steel. Instead of using wires for conductors, small slotted tubes are hung

FIG. 48.



THE BLACKPOOL CONDUIT.

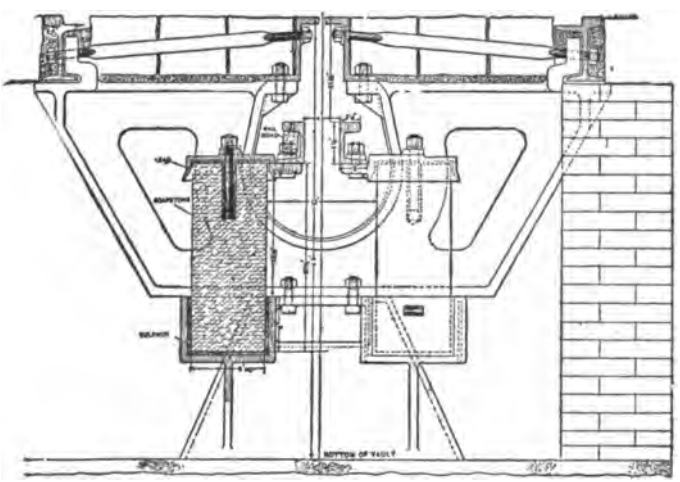
on insulators to carry the current. The pressure is three hundred volts, the figure to which European lines are usually restricted, though that used on trolley lines in the United States is almost universally five hundred volts.

Another conduit road is being built in Washington, D. C., by the Metropolitan Railroad Company for its Ninth Street line, on plans made by Engineer A. W. Con-

nett. A central conduit of good size is used, and small T-shaped rails are used as conductors, the contact plough sliding between them. The castings that form the yoke being large and substantial, the drainage arrangements excellent, and the climate of Washington moderate, success is anticipated.

The Metropolitan Traction Company of New York are equipping an experimental line on Lenox Avenue which has some new features. A continuous vault more than three feet deep extends under the whole line, having a concrete floor and brick walls, on which the tracks rest and which afford support to the yokes or cross-supports. The

FIG. 49.



THE LENOX AVENUE CONDUIT, NEW YORK.

conduit is of sheet iron and about fifteen by twenty-five inches, and its slot-rails are supported in the firmest manner by bolting to the yoke and by occasional rods connected with the rails of the track. The conductors are remark-

ably heavy, being formed of four-and-a-half-inch rails, supported on soapstone piers at thirty-foot distances, with intervening lead insulation. The piers rest in sulphur-lined troughs, which arrangement would seem to be amply sufficient to protect them from leakage. There is a man-hole at every insulated pier, to render access easy. Very little moisture can enter the narrow slot, and the snow would have to drift in to a height of over two feet before it reached the conducting rails. The contact-shoe slides on the conductors. This is the first Northern road that gives promise of success, which its excellent construction would seem to insure.

It will be noted that all the successful roads, and those which promise success, make use of two conductors in the conduit, with a travelling device for making a connection between the two and receiving the current. It is admitted by electricians that a single wire or conductor could be used, and many such have been devised, but never got beyond the experimental stage, as the double wire has more advantages in practice. Various patents have been secured for devices for protecting the slot so that snow and water could not enter, and interfere with the service by inducing leakage of the electrical current. Professor Elihu Thomson is the inventor of one, which consists in closing the slot with a series of wire brushes, which would bend aside to permit the passage of the plough. He proposes to use either a single or a double brush, as may be desired. The Van Depoele conduit patent proposes the use of two strips of flexible material to cover the slot. There are a number of other patents of the same sort, most of which are valueless, since there is no known flexible material but what would be subjected to ruinous wear in being constantly rubbed by the ploughs and exposed to all weathers. A

better idea is that of A. F. Petersen Griffin and other inventors, who place the conductors to one side in the conduit, and protect them with a shield, so that the water cannot reach them. This involves a much-twisted form of plough, and probably for that reason has not yet been adopted.

Other inventors have been attracted to the idea of making the whole conduit of insulating material, and others to the introduction of heat to preserve the needed dryness. Either method is feasible, but the cost involved is serious.

What is known as the surface-contact method has been tried by many devisers of systems, and two or three of them have been put into actual use in an experimental way. One is the Wheless system, used on a short line in Washington, D. C., which seems to be the city for nascent enterprises of an electrical nature. This makes use of contact-heads or plates placed at distances of less than a car-length between the tracks, an electro-magnetic switch being fastened to the under side of the contact-plates, so that, while the car may easily make contacts between the switches, their distance prevents annoyance to other vehicles, and the switches themselves are amply covered and protected by the plates. Wheless has also tried a modification of this system in which he makes use of a continuous slot. The other system referred to is the Johnson-Lundell, which is being tested in New York. A brush or roller is carried beneath the car, to collect the current from sectional rails or bars which are placed at intervals, under the control of magnets. It is necessary to use a storage-battery of small capacity to start the car and to furnish power to carry it over crossings, etc. There are probably a hundred patents making use of the switch principle, which consists

in having a number of individual switches operated in succession by a contact device which shall always cover at least two switches, so as to maintain the current. The Lawrence system has been tried at Wilmington, Delaware, consisting of sectional rails, operated by means of a trolley through a slot, the rails being thrown into contact with a current by leverage as they are passed.

Among other proposed systems is the Feltrow raised conductor system, in which the conductor wire is drawn out of the slot as the car travels over, and dropped back again after having given off a portion of its current. The Perrin system is an oddity, since the cars have neither trucks nor wheels, but are supported by a motor within the conduit by means of stout bars projecting from the slot.

Amid a multitude of counsellors there is wisdom, and among the many hundred devices that have been proposed no doubt some will be found sufficiently practical to be introduced wherever electrical propulsion is demanded but the overhead trolley forbidden. Experience seems to indicate that such a system will make use of the open slot, and use a low voltage, perhaps not over two hundred and fifty, and that these features, together with great attention to details in the matters of insulation and avoidance of leakage, will result in success for conduit electric railways.

A HUNDRED AND TWENTY MILES AN HOUR.

Railroad Speed that is not only Possible but Very Probable in the Near Future, by the Brott System of Rapid Transit.

IT is generally conceded that sixty miles an hour is the practical limit of speed on steam-railways, as at present constructed. It is rather startling, therefore, to be told that a company has been formed and that capital has been obtained for the purpose of erecting a railway which will bear trains at double this speed. A hundred and twenty miles an hour is a speed that, if maintained, would carry one around the world in a trifle over eight days. It is faster than the hurricane, the carrier-pigeon, or anything else that moves upon this mundane sphere. Yet the National Rapid Transit Company is asking the United States Senate for privileges looking to the establishment of a line between New York and Washington, and specifying in the proposed bill that the schedule-time shall not be less than one hundred miles an hour, which necessitates a speed of a hundred and twenty miles per hour to cover loss from stops. Further, the General Electric Company of New York is willing to guarantee motors, generators, and other electric mechanism for such a road, warranting them to maintain a speed of one hundred and fifty [note the fifty] miles an hour when delivering a hundred horse-power per motor, with two motors per car.

All this is possible through what is known as the Brott rapid transit system. This system makes use of what is miscalled a bicycle railway. It is not a bicycle construction in any proper usage of the word, which means two wheels; but the likeness to the bicycle is found in the fact

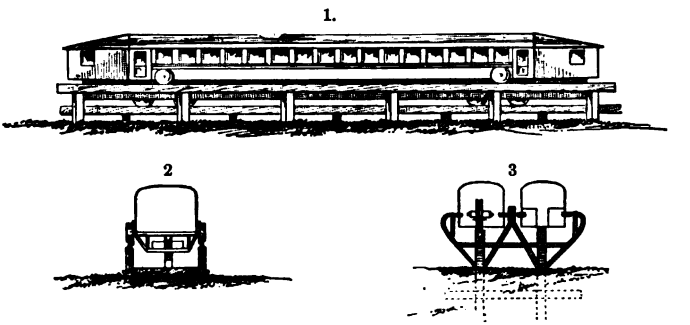
that the supporting wheels are in line and run on a single rail, instead of on a parallel track, as in the ordinary railway. It is an elevated road, as no chances can be taken with grade crossings. The supporting wheels—or traction wheels, as they are called—have very wide flanges to keep them on the track, and balance is assured by side wheels which may occasionally touch the side stringers if the cars oscillate a little. It is well known that a body running on wheels arranged in a line tends to remain upright, so that these side wheels will have little to do except when a train is starting or stopping. These side wheels are to have pneumatic tires, to prevent jar to the passengers when they impinge against the stringers. The cars are to be made of steel and vulcanized timber. The electric motors will be of the gearless type, operating directly on the axle, one on each side. The electric current will be taken from a conductor on the trolley principle, and power-stations will be erected about fifty miles apart to supply the current by feeder-wires to intervening points. The conductor, which will be almost too large to be termed a wire, will probably be carried under the cars instead of overhead. It will deliver the current to the car-motors at a pressure of one thousand volts, double that used on street-railways. The generators at the power-stations will develop it at ten thousand volts, and transformers will be used to reduce it as it reaches the conductors. The three-phase alternating current system will be used.

The elevated double-track construction is such as to mutually brace the tracks. An even grade will be maintained by simply altering the length of the poles, which will be cheaper than the building of embankments and cuttings necessary in the construction of surface-roads. An almost absolutely straight line will be preserved, as

curves interfere with speed. The supporting poles will be about twenty-five feet apart, and will be set into underground sills and braced below the frost line. Light trains, preferably of two cars, will be run, and, as the system is entirely express, a higher rate of fare may be expected than is charged on existing lines.

An experimental single-track line of thirty miles is to be built between Washington, D. C., and Cheasapeake Bay, on the design shown in the illustration. The con-

FIG. 50.



THE BROTT ELECTRIC BICYCLE RAILWAY.—1. Car of Washington and Chesapeake Bay Line. 2. End view of same. 3. Double-track construction.

struction is most economical, requiring no iron or steel except for the track-rails. It will be observed that the cross-sill or tie rests on the ground, and to it are secured the posts that support the stringers and side rails. The centre stringer has supports midway of each span, and being so near the surface the roadway will have all the strength and stability required. The centre rail will have normally an elevation of about two feet, except at road-crossings, where it will be elevated to afford passage underneath. The cross-ties may lie on the ground or be elevated, as the

nature of the ground renders desirable. A steel-truss construction will be used in crossing rivers or deep gullies. The wood used in construction is to be subjected to a preserving process. The peculiar story-and-a-half design of the car should be noted, the half-story being below, and constituting a room forty feet long, six feet wide, and four feet high, suitable for carrying baggage, the mails, etc. It is reached by outside doors. Above is the compartment for passengers.

Another line is projected in the vicinity of Minneapolis. The simple construction would seem to be well suited for pleasure railways and light passenger traffic, and the success of these lines would undoubtedly lead to the construction of express lines between the great business centres of the world.

It is interesting to consider the reasons for believing that it is practical to maintain the high speeds possible with this system. The principal resistance to speed is, of course, frictional, and in the case of a railway is of three sorts—flange friction, journal friction, and rolling friction. As a bicycle railway-car will tend to stand upright without mechanical assistance, the side friction of the flanges will be reduced to a minimum. A reduction in the curves of the track will also effect a saving, and between the two the saving of flange friction ought to be at least seventy-five per cent. Journal friction can be reduced in about the same proportion by using modern steel-ball bearings. Rolling friction can be reduced by the use of lighter cars. It does not amount to much, anyway. Locomotives have a reciprocating motion of the pistons that cannot approach in speed the rotary motion of an electric motor. With every stroke the piston and connections have to come to a dead halt and be reversed. A rotary motion is continuous, and in practice

admits of certainly twelve times the speed obtainable with an equivalent reciprocating mechanism. Improved tracks, having no severe grades or curves, will do the rest.

How about the resistance of the air? some one will query, at this point. It is scarcely worth figuring on. If air-resistance increased with the square of the velocity, as many have maintained, how would it be possible to fire a projectile twelve miles with a single impulse? It is now claimed that it does not increase in that ratio. Mr. F. O. Crosby has demonstrated that air-pressure increases with the velocity, so that at one hundred and sixty miles an hour there would be twice the resistance as at sixty miles an hour. It remains to be seen whether his conclusions will be accepted by physicists; but whatever this resistance may amount to, it is in practice reducible about two-thirds by making the forward end of the train in the form of a pointed cone, so that the air simply glances off.

Engineer F. L. Averill, of Washington, who has figured on this problem, says that nine hundred and forty-seven horse-power would be sufficient to drive a train of the character described one hundred miles an hour, on a two-per-cent. up-grade, against a head wind blowing thirty miles an hour. He adds:

"The tractive force necessary to move the train in this last example requires a total weight on driving-wheels of eleven thousand eight hundred pounds, far within the necessary weight of motors and cars.

"The power shown above to be necessary would require only from eighty to one hundred and eighteen horse-power motors to be applied to each of eight driving-axles. With six-feet drivers, to make one hundred and fifty miles per hour would require seven hundred revolutions per minute. That the power and velocity of motors would

be well within present possibilities goes without saying.

"The electricians say that there is no difficulty likely in conducting the electric current from a trolley-wire to motors at this speed.

"Lubrication seems without difficulty, provided that all wheels are made somewhat larger than in the present railway cars and that the journals are ample in size to reduce the pressure on bearings.

"It would seem as if the promoters of high-speed projects had only to provide first-class machinery, cars, and roadway, taken with a good system, in order to fulfil their expectations with perfect safety. The benefits from such a high-speed service are incalculable. The influence upon commerce and all business would be marked. The great economy of time in travel and transportation would greatly stimulate both, and ought to bring a golden return to the successful project."

The whole plan is so entirely practical that it is only a matter of time when such roads will be established between all important points. The substitution of the electric motor and special devices for fast travel may be delayed by the managers of steam-railways, whose business will be injured thereby, but the change has got to come. Present methods are not in keeping with the progressive science of the age. The steam-roads carry a ton of car-weight for every passenger they transport, where only four hundred pounds are required with the new system. The slaughter of people by crossing roads built at grade on the surface must be stopped, and this is one way to avoid it. Why should the mails occupy twenty-four hours in transit between New York and Chicago when the distance can be covered in eight hours? Why should passengers be

bothered with sleeping-car accommodations to make a journey that can be accomplished within the short hours that now constitute a legal working-day?

In the Brott system locomotives are dispensed with. The motors are on the axles, under the cars. Hence it is possible to dispense with the mighty locomotive, that has to be made nearly as heavy as the whole train in order to secure a proper hold upon the track. Now that ocean steamers have so closely approached railroad speed, it is high time that the land roads forged ahead before designers of water craft catch up.

THE MANUFACTURE OF STEEL.

Improved Methods which have cheapened Steel—Bessemer's New Process for rolling Fluid Steel.

THE very low price at which steel is now sold and the vast increase in its use afford the plainest evidence of improved methods of manufacture. Sir Henry Bessemer gave us a cheap method of making steel, so that it was at once brought into common use. Both British and American steel-makers have improved on the original process, and to-day steel is as common and as low in price as iron. That structural steel can be sold for one and three-tenths cents a pound is a marvel that can be accounted for only by noticing the steady progress of improved methods. The development in steel-making has been greater on this side of the water than in England or on the Continent, and that this is recognized appears from a quotation from a paper read by Sir Henry Bessemer a few years since before the Iron and Steel Institute of Great Britain, in which he says,

"Our American cousins . . . are prompt to recognize, to adopt, and to improve upon the inventions brought forward in Europe."

Perhaps the best way to give the reader an idea of present methods employed in steel-making will be to describe one of the latest and largest plants established. In June, 1894, the Johnson Company, having decided to leave their works at Johnstown, Pennsylvania, and build greater, began the erection of a Bessemer steel plant at Loraine, Ohio. As a preparatory step they purchased four thousand acres of ground and obtained four miles of river front contiguous to Lake Erie. They also built an electric railway from Loraine to Elyria, a distance of ten miles, on which they run their trains at from thirty to forty miles an hour. Three thousand men were set at work, and within ten months the manufacture of steel was begun. The buildings of the plant are a power-house, bottom-house, cupola building, converter-house, stripper-house, furnace building, boiler-house, blooming-mill, Bessemer boiler-house, roll-shop furnace building, roll-grinding building, shape-mill, hot-beds building, straightening buildings, cold-finishing building, and splice-bar shop. As several of these buildings are from three hundred to five hundred feet long, the magnitude of the plant can be inferred. Six thousand two hundred and fifty feet of trenches were dug for the sewerage and water-supply, and over two miles of narrow-gauge tracks were laid to connect the buildings and handle the material. The boilers supply nine thousand horse-power. A large dam was built, where sixty million gallons of pure water can be stored.

In the bottom-house is a plant for preparing the refractory material with which the converters are lined.

The power-house, which is two hundred and twenty-two

FIG. 51.

BESSEMER CONVERTER HOUSE AT LORAIN, OHIO.

feet long, contains a very powerful blowing-engine of the latest cross-compound type, and two pressure-pumps and an accumulator, to furnish and regulate the hydraulic service throughout the plant. There are six thousand feet of pipe in the hydraulic service, all laid in accessible tunnels, so that leaks can be promptly mended. Two steam-pumps are used to supply the water, and these have a combined capacity of two million five hundred thousand gallons. Four large dynamos and one arc-light machine, with directly-connected engines, are used to supply power to the electric road, while another large engine and dynamo furnish power to the various electric cranes.

The pig-iron is melted in four cupolas in the cupola-house. Each of these is twenty-five feet high. They receive blasts of air from mammoth tuyere-pipes. All deliver at a common point—above the track on which stands the iron ladle used to carry the metal to the converter-house. In the latter building are two of the largest converters ever made. Each will hold twelve gross tons of metal. These converters are great metal retorts mounted on central trunnions, like a cannon, so that they can be tipped and poured. In them the pig-iron is converted into steel by the Bessemer process. When the metal is ready the converter is tipped by great gear-wheels, and the molten steel run out into a twenty-ton ladle-crane, which serves both conveyors, but which is so carefully mounted on ball-bearings that it can be operated by a single man. The steel ingots are cast into cars, and are made in two sizes, weighing five thousand five hundred and six thousand five hundred pounds respectively. The cars bearing the moulds are moved along slowly by hydraulic power while the pouring is going on. This and all the other operations in the converter-house are controlled by

levers from a "pulpit" that stands within view of all the mechanism.

The ingots go to the heating-pits, where there are two furnaces, each with six pits, and each pit having a capacity of four ingots. The pit covers open as if by magic, but really by means of hydraulic cylinders. Arrangements of air-valves are provided for each pit so that high or low carbon steels can each be heated to the proper temperature in adjoining pits. Overhead travelling-cranes of fifty-two feet span serve to handle the heavy ingots, lowering and raising them as desired. The power used in gripping is compressed air, the compresser itself being run by an electric motor. The longitudinal and lateral movements of the crane are performed directly by the electric motor.

From the heating-pits the cars are run to the blooming-mill table. For the benefit of those who are unfamiliar with the language of steel-making, it should be stated that a blooming-mill is the first set of rolls through which the metal is rolled, after which it is relieved of slag, made malleable, and is called a bloom. The mill shown in the illustration is of thirty-eight-inch size, and contains in its framework some of the largest castings in the world. A special train had to be devised for bringing six of these castings from Pittsburg, where they were made. Two of them weighed sixty-eight thousand pounds each, two sixty thousand each, and two forty-eight thousand each.

This big blooming-mill requires the services of a ten thousand horse-power engine, which is directly coupled to one of its shafts. Smaller engines are used to work the rolls that lead up to the squeezing rolls of the train. An hydraulic manipulator, consisting of two jaws, is used to handle the hot billets. The engine and blooming-mill are both operated by levers from one platform by two men.

FIG. 52.

THE JOHNSON COMPANY'S BLOOMING-MILL.

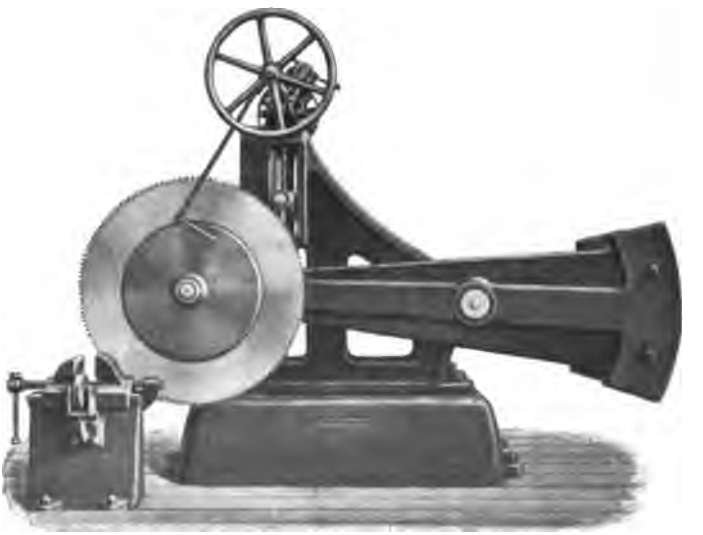
Such perfect arrangement and almost entire abolition of hand-labor are the secrets of the improvements in steel-making. Adjoining the blooming-mill is an hydraulic shear for reducing the blooms to the desired length. It makes nothing of shearing a seven by nine piece of steel. From this shear the blooms are rolled along on one of two tracks by hydraulic power. Defective blooms are swung by a jib-crane to a steam-hammer for chipping. The rail-blooms, as they come from the shears, are taken to re-heating furnaces, of which there are three with fourteen-by-thirty-foot hearths and eight working-doors on each side. Both the charging and delivery are controlled by electric overhead cranes, and the bloom-tongs are also electrically controlled.

The rail-mill is something of a novelty. In the centre stand the roll-trains, and on either side are carriages moving at right angles to the train over a row of live rotating rollers. There are three of these carriages on each side of the train. They assist in passing the blooms back and forth through the first set of rolls, called the roughing rolls; then the carriage and rails are conveyed bodily by geared cross-tracks, or racks, to a position opposite the next set of rolls, and so on. All the movements are carried out by means of electric motors mounted individually on each carriage, and all is controlled by levers and switches from two "pulpits" on either side of the train. The stands of rolls are changed when desired by means of a forty-ton electric crane of forty-eight feet span. Twelve spare stands of rolls are kept for changes, and a stand can be removed and another put in its place in less than an hour.

Beyond the rail-train extend the delivery-tables, with three steel-saws, such as that shown in the illustration. These saws run at an enormous velocity, and sever the

rails by melting or burning. Here is also a cambering-machine. At right angles to the tables are two series of hot-beds, to either of which the rails may be moved by a pusher worked by a wire rope. These hot-beds will ac-

FIG. 53.



THE SELLERS STEEL-SAW.

commodate girder-rails as long as sixty feet. The arrangement of the hot-beds divides the product of the mill into two parts, each of which has its own straightening-shed. Eight automatic rail-straightening machines are employed here. Next the rails go to a finishing-mill, in which the ends of the rails are milled off, drilled, and fitted. They are then delivered to the cars for shipment.

The two boiler-houses are supplied with coal by automatic contrivances, so that there is no touching of the coal by hand from first to last. Electric elevators and con-

veyors bring in the coal, and it is fed to the boilers by Murphy mechanical stokers. Slack coal is used, at a cost of only ninety cents a ton delivered, so that the power is obtained very cheaply.

In the manufacture of cast steel the progress of recent years has been as marked as in that of rolled steel. Soft-steel castings for plate armor were first made in this country about 1886. The castings of that period were very porous, the use of silicon for solidifying the steel being then unknown. Along in 1876 hammer-heads and dies of moderate size were cast satisfactorily, but large castings were imperfect, and the moulding-sand adhered to them with great tenacity. By altering the moulding mixture, and washing the mould with finely-ground clay fire-brick, a considerable improvement was obtained. But the change in mixture was not suited to complicated shapes, because it offered resistance to the shrinkage, so that there was a tendency to crack. A mixture of silica sand and flour was then tried, with good results in the case of small castings. The difficulties in the way of good castings were largely removed later by the introduction of silicon in combination with the steel, for assisting solidification, and by the use of a mixture of moulding-sand consisting principally of silica sand and molasses thoroughly ground together.

Steel castings are ordinarily hard to clean, but they yield under the effective influence of the sand-blast. The machine used for supplying the sand has the appearance of a vertical boiler, fitted with the necessary mechanism of feed-valves, sand chambers, etc., so arranged that an air-pressure of about ten pounds per square inch catches the sand and delivers it through a pure rubber hose, which must be handled in such a way as not to kink, because a sharp bend is always liable to be cut by the sand. In use this

hose is turned on the castings and sand poured out under pressure, much as a garden would be watered with a hose attached to a water-supply.

While it is now possible to buy steel castings of excellent quality and uniformity, in order to be sure of such it is usually necessary to patronize one foundry making a specialty of small castings, and another foundry making a specialty of large castings, and perhaps a third making a specialty of thin castings, such as are used in stoves. The business involves a large amount of individual skill, and minor conveniences for different grades of work.

FIG. 54.

THE MANUFACTURE OF STEEL TRUSSES, AS CARRIED ON BY THE BERLIN IRON-BRIDGE COMPANY.

Sir Henry Bessemer has recently proposed an improved method of making thin steel plates direct from the fluid metal, instead of casting into ingots and rolling down as is now done. His plan is to allow the metal to flow from a reservoir, in small streams of regulatable size, between

two large rollers, which rotate slowly so as to chill the metal, at the same time drawing it in so that it passes out as a thin sheet of steel, and is led away by curved guides between other and smaller rolls that steady it so that it can be sheared off at desired lengths and piled up in a stack. With such an apparatus, Mr. Bessemer thinks that he could make a ton of plates the twentieth of an inch in thickness in seven and a half minutes. If this process proves to be the same in practice as in theory, the manufacture of steel plates of less than an inch in thickness will be revolutionized.

MACHINE TOOLS.

The Ingenious Machinery that has been devised for building other Machines and manufacturing Material for Metal Structures.

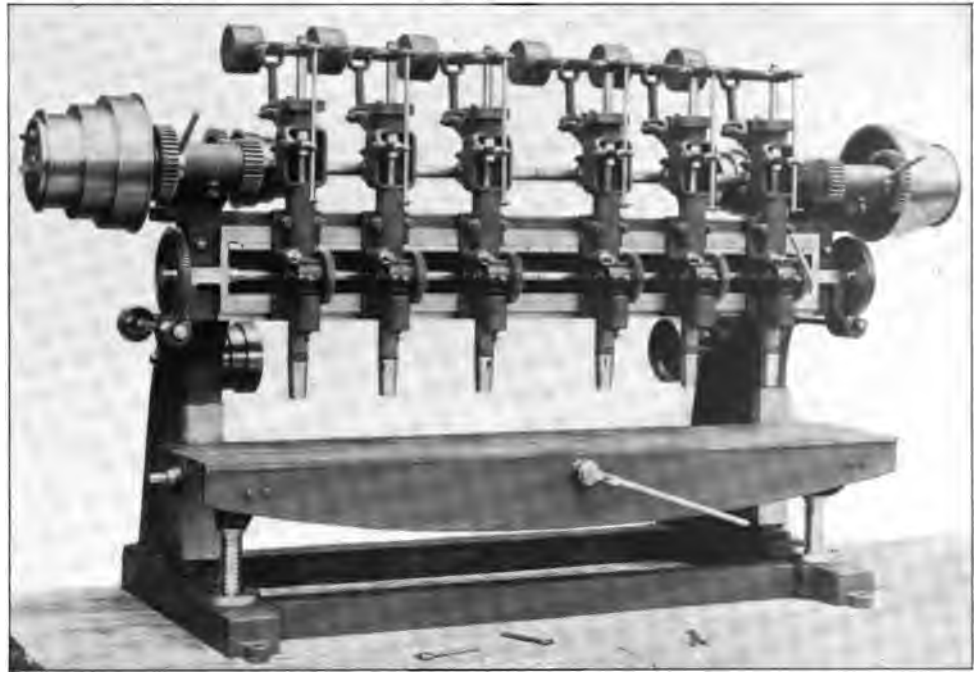
THE cheap and rapid production of machinery of all kinds possible by modern methods has only been attained by the development of machine tools or—to state it more clearly—special machines, whose office is to assist in the making of other machines and structures required in the various industries of the world.

One of the commonest operations in the making of machinery is the forming of a hole for some purpose, as for admitting bolts or rivets to bind the parts together. Such holes in metal-work are formed in four different ways. If in a casting, they may be formed conveniently in the mould, if over one inch in diameter and so situated as not to entail any serious difficulties in drawing the patterns from the moulding-sand. If in wrought iron, steel, etc., they may be punched, provided the plates are not over an inch and

a half thick or the holes more than four inches in diameter or thereabouts, and provided further that great accuracy as to the form of hole is not requisite. For the majority of small holes, however, the drilling machine is required, and for large holes the boring-mill. The unsophisticated may inquire what is the difference between drilling and boring a hole. In common language the two words are used interchangeably, but among machinists to drill is to cut a small hole out of solid metal with a tool that rotates about its centre, while to bore is to shape a large hole by means of a cutter that may be set out of centre and will shape a hole of the diameter of its rotary motion. In other words, a drill turns in the middle of a hole, cutting all sides at once, and cannot be used for large holes because it would require too much power, while a boring-bar will carry a tool that will travel around the edge of a large hole, taking off a chip or shaving that requires little power.

The every-day drill-press is a convenient tool, to be found in all machine-shops, but as it bores only one hole at a time, and usually has a hand-feed to avoid danger of breaking the drills, its operation is too slow to admit of some mechanisms being produced at low cost. To reduce cost of the manufactured product there have been introduced a variety of multiple drills that will form a large number of holes at one operation. There are two-spindle and three-spindle rail-drilling machines, for making the holes by which railway rails are connected through the medium of fish-plates. Four-, six-, and eight-spindle machines are made for use in boring holes in rows, at spaced distances, a very common requirement. One of these is the Niles multiple drill shown in Fig. 55. This has six spindles, three of which are driven from one end and three from the other end, by the cone-pulleys, securing

FIG. 55.



THE NILES MULTIPLE DRILL.

more power than could be had if they were all driven from one pulley. The table is provided with water-trough and power-pump for keeping a continuous supply of lubricant on the work during drilling. This arrangement of drills is of great advantage when holes of different size and depth are to be drilled at the same time in the same or different pieces. A somewhat similar machine is made with three spindles for either drilling or tapping holes. Tapping is the cutting of an internal thread in a hole so that it may receive a screw. Another form of multiple drill has a circular table for the work, and as many as twenty-two drill-spindles above it, so that numerous holes of odd or irregular arrangement may be drilled at one time. The drills are arranged in two groups, one group having a faster speed than the other for use in boring smaller holes or in softer metal.

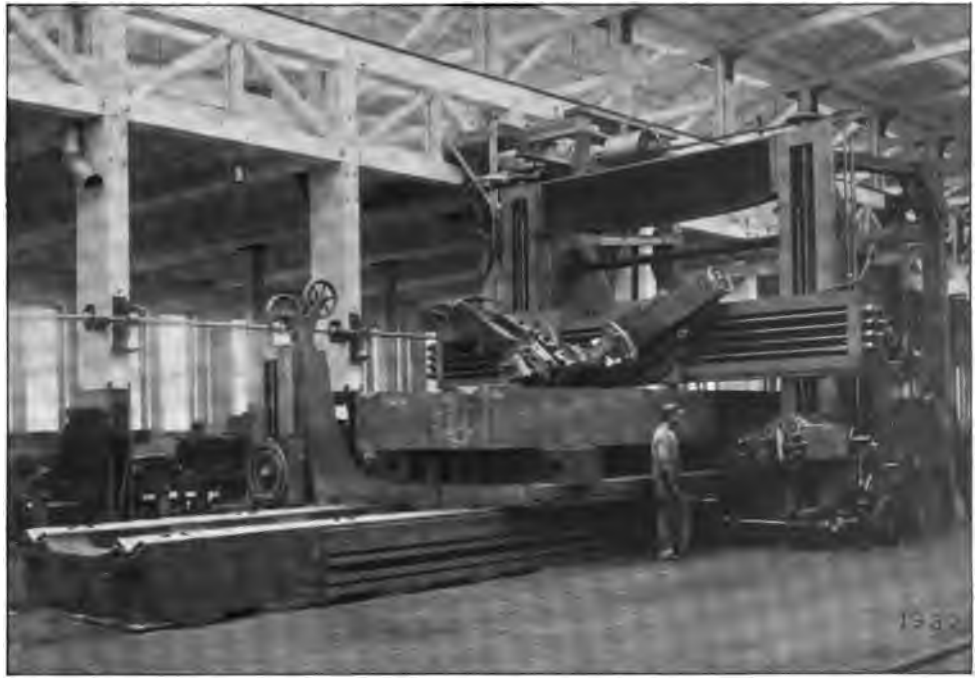
William Sellers & Co. build universal drilling machines arranged so as to drill the hole in any required direction. Large work can be run alongside and drilled with great facility. The same firm build a radial drilling machine that has a radial arm for the drill, and will make a hole anywhere within a radius of eighty-three inches. In these machines the arm is hinged to a saddle carried upon the face of a rectangular column or upright. It is easily rotated by hand, and is raised and lowered by power by means of a hand-lever. The arm is thus quickly adjusted to the proper height to suit the work, and, as the saddle that carries the tool is so fitted and is of such length as not to require any clamping to place, this adjustment of height is rendered extremely simple.

A variety of horizontal drilling machines are made that resemble in general appearance a lathe, but have no dead centre.

Boring machines are made of both horizontal and vertical form, the most familiar type being the upright boring- and turning-mill shown in Fig. 56. In this style there are three saddles for bearing the boring-tools. The housings, or large upright members, may be moved forward or back according to convenience, being retained in the forward position for small work and run back when in the way of larger work. The circular table in front is arranged so that it will rotate the work, and has large radial slots for bolting the work on solidly. Horizontal boring-mills are also made that are adjustable to the work, and convenient where very heavy castings are to be bored.

Punching machines usually resemble a very thick-set full-face capital **G**, this form giving the strength which is required between the opposed sides and permitting the piece punched to pass between the jaws. They are ponderous and weighty. The largest sizes will exert a punching force of half a million pounds, with an overreach of four feet—that is, with the punch at a distance of four feet from the backbone of the machine. Shearing machines are frequently combined with punching machines, the general construction being the same. The shearing is done by flat, hardened surfaces of steel that slide past each other much like the blades of a pair of scissors. For punching fish-plates, angle-irons, or other work not of very heavy character, multiple punching machines are manufactured, some of which make as many as six holes at once. Punching is much cheaper than drilling, since it can be accomplished more quickly, but as it tends to weaken the material in a slight degree it is not always preferred. Shearing machines for trimming the edges of iron plates are made of a strength and capacity sufficient to take off an edge sixty inches long and an inch thick.

FIG. 56.



UPRIGHT BORING AND TURNING MILL.

UNIV. OF MICH.

These are principally used by bridge-builders and in shearing the metal plating for iron or steel ships.

Riveting requires much less strength on the part of a machine than do punching and shearing, yet the steam-riveter shown here is a very heavy machine, of William Sellers & Co.'s make, and presents a six-foot gap for the work. It operates by pressure, and not by hammering. The result is preferable to riveting accomplished by a succession of blows on the head of the rivet, because in the squeezed rivet the shank is upset so as to fill the hole completely before forming a head, and the parts that are being riveted are brought into close and firm contact; but in hammering, either by hand or power, the head is formed without necessarily upsetting the shank throughout its length, and the rivet is almost certain to be loose in some parts of the hole, especially if the punching does not match exactly, and the plates are not clamped together with the same solidity as where pressure is used. Hydraulic riveters are also made, which operate by pressure and do excellent work. They are of practically the same pattern as the riveter shown here, but water instead of steam is used to force in the pressure-cylinder. Some of them are made with an auxiliary cylinder for tightly clamping the plates so that their surfaces are brought rigidly together, a necessary thing in boiler-making or the like. Riveters are made as large as sixteen feet between the jaws—that is, of a size to fasten a rivet in the centre of a plate thirty-two feet square.

FIG. 57.

STEAM-RIVETER.

The wheel-press is a modern special machine that has attained a wide field. It is designed for pressing on or off a wheel—as of a locomotive—from its axle. It is often operated by hydraulic power. The operation is easily understood. The axle is swung into proper position by central hooks, one end resting in a resistance-post. If a wheel is to be put on it is then crowded between the cylinder and the axle, and the pressure of the water in the hydraulic cylinder exerted to force it on. A pressure of about thirty tons is required to put on a car-wheel sufficiently tight to insure its never coming off by accident. A much greater force has to be exerted at times to remove it, and therefore the larger sizes of these machines are given a capacity of two hundred tons.

Though the above description does not by any means cover the extent of machines that have to do with hole-forming, yet it may serve to give the reader who is not informed on the subject some idea of the general methods employed in this department of machine-construction in the largest and best shops in the United States, which is equivalent to saying "in the world," for in no other country has machine-construction attained as high a development as in our own.

Machine tools for shaping and forming are most varied in their construction, including the indispensable lathe, planing and stamping machines, bending-rolls, slotting, gear-cutting, grinding, and numberless other mechanisms. It is believed that the first lathe made by primitive man was formed by tying a thong of hide to a young tree, passing it around some piece fixed at both ends so as to rotate when the lower end of the thong was pulled. By tying the free end of the thong to his foot the primitive man turned the rotating piece one way, and by lifting up his foot the spring

of the young tree turned it the other. Then, by pressing against the rotating piece with a sharp-edged stone it could be formed into circular shape. Such is the principle involved in the lathes of to-day, but the primitive man would hardly recognize any of them as evolved from his handiwork.

A machinist's lathe, as ordinarily constructed, has a frame with a pointed centre at each end, between which the work to be turned is hung. One centre rotates, and is called the live centre, while the other centre is called the dead centre because it has no rotary motion. The mandrel of the live centre is driven by pulleys, of graded speeds, and there is usually a face-plate to which work may be attached. The cutting-tool is mounted on a travelling carriage, so that the workman can cause it to pass back and forth over the surface of the work and cut it in almost any circular or conic form.

Lathes are made in a seemingly endless variety of forms, suited to special work. A recent form is the turret-lathe, which has a cylinder set upright on an axis so as to slide over the ways, the cylinder having several faces with chucks or spindles for the reception of drills or other tools, any one of which may be presented in succession in the axial line of the work. When a lathe is fitted with two cutting tools operating at once it is termed a duplex lathe; if there is an abrading wheel, it may be called a grinding lathe. Many lathes are fitted for drilling or boring. Some are provided with two driving-heads, for turning at a single operation two mounted car-wheels or the like.

Planing machines are designed to reduce a level or flat surface by taking off continuous chips or shavings in parallel lines. The common form has a bed that carries the work back and forth between a heavy framework, on which

is mounted the cutting tool. Rotary planers are used, however, that have twenty-five to seventy-five cutting tools arranged on a powerful wheel, mounted on a saddle, that travels back and forth while the work remains stationary. They are much used in shaping bridge-work. For planing large plates there is used a type of machine having a long plate girder to hold the tool to its work. The tool travels back and forth and bevels or otherwise shapes the edge of the plate, being held down to its duty by a stout clamping-bar. It is used for planing boiler-plates, safe-plates, and the like. Other plate-planing machines are made with very stout carriages, so that they do not require a clamping-bar. The Niles Tool-Works Company also build a gigantic machine for planing and slotting that is mounted on a railway track below the level of the floor, as shown in Fig. 59. Large work may be clamped to the adjoining floor-plate, and is planed by the travel of the planer on its railway. This powerful machine has a bed-length of thirty-eight feet, and will plane to a width of almost nine feet. Its uprights are sixteen feet high, and it is driven by a long belt carried under the ceiling.

Slotting machines are sometimes built like planers, though the more common form has a tool that receives an up-and-down motion from a crank-wheel. A chain slotting machine has been recently introduced that has a series of cutters mounted on an endless chain. It is chiefly useful for such wood-work as mortising door-frames. The gear-cutting machine is a form of slotter, since it shapes the cogs and spaces. This machine has been brought to a high degree of perfection. Though the teeth of a gear must be very accurate in form, and every change in size of the wheel or in the number of the teeth involves a change in the form of each tooth, yet gear-cutting machines are

FIG. 58.

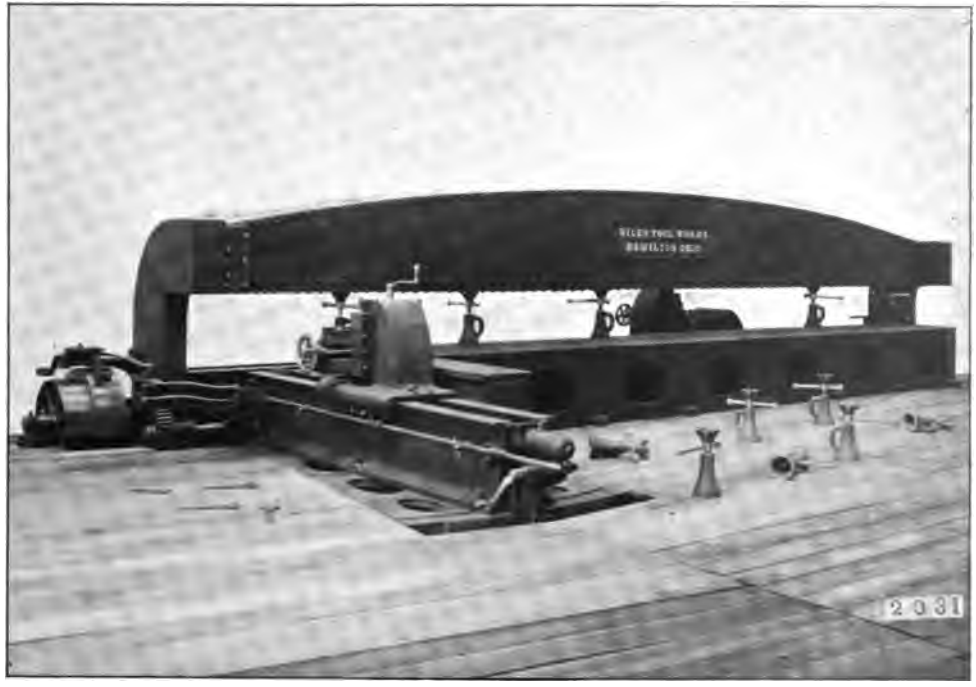
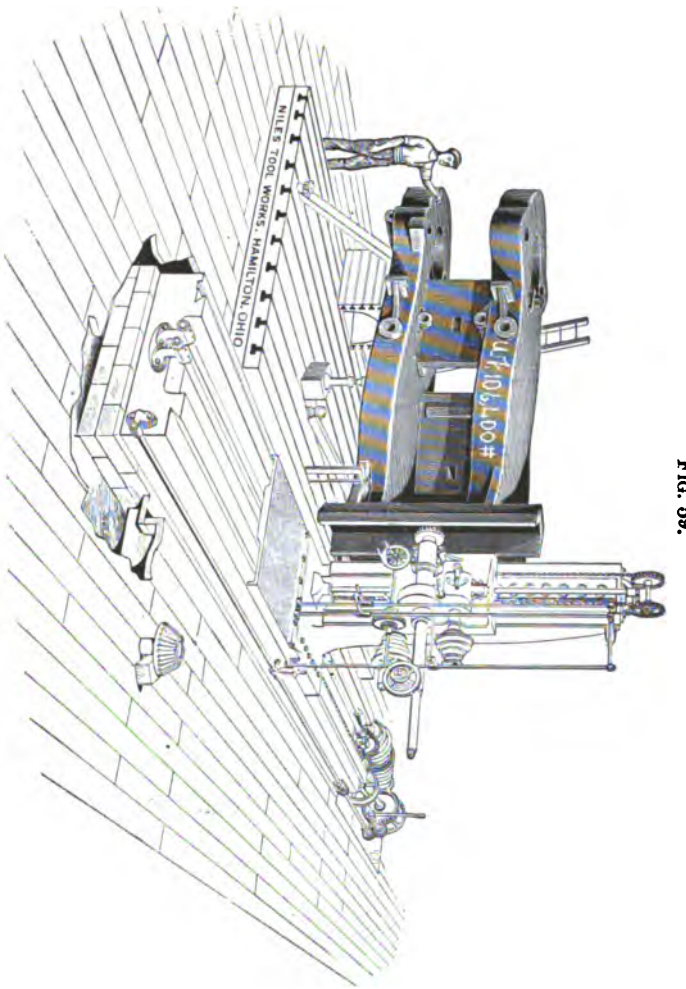


PLATE-PLANING MACHINE.

UNIV. OF MICH.



PLANING AND SLOTTING MACHINE.

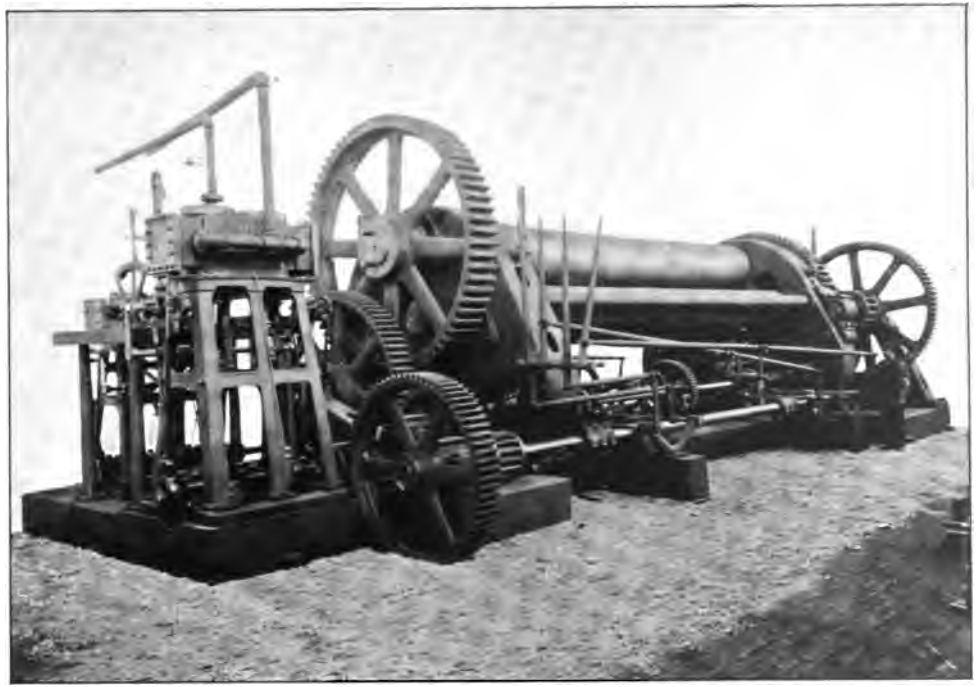
Fig. 59.

mostly automatic, and divide off the teeth and cut them from the solid metal blank with only the most trifling attention. One man can run four of them at a time. A blank wheel being put in place, and the proper cutter adjusted to depth of teeth, length of stroke of cutter-head, etc., the cutter will pass across the face of the space between teeth, and return at a quick pace to the starting side of the wheel, while the blank is automatically shifted so as to present the next space to be cut, and the cutter starts in to do its work again.

Milling machines are used to finish and shape parts of machines by means of rotating cutters. Shapers are really small planing machines adapted for light and rapid work.

Stamping presses are used to shape parts of wrought iron or steel. Many forming machines are operated by hydraulic power. For stamping coins the approved form is an hydraulic press with very heavy frame, and dies between which the coin or medal can be pressed to form. The Philadelphia Mint uses a machine that exerts a pressure of two million pounds. It consists of two semi-circular heads, separated by strong columns, and united by heavy steel bands, between which is a cross-head operated by a large steel cylinder in the upper head and small return cylinders in the lower head. Power is supplied by a direct-acting plunger-pump, which maintains a constant flow of oil from an overhead tank. The movement of the coining-head is controlled by a lever. The pressure applied is determined by an adjustable safety-valve. The head is made to move at the rate of an inch a minute when under pressure, and three feet a minute when coming towards or from the work. This same form of press is used for punching and stripping, or may be made to do the work of a drop-press or fly-press.

FIG. 60.



MACHINE FOR BENDING METAL PLATES.

The bending of plates of metal is accomplished between sets of rolls, which may be adjusted so as to give any curve to the plate. Four rolls are commonly used, one pair being larger than the other two and being used for compression and to carry the plate. The smaller rolls do the bending. The machine, Fig. 60, is of the largest size made in this country, and will bend cold steel ship-plates twenty-two feet wide and two inches thick. It was built by the Niles Tool-Works for the Mare Island Navy-Yard, and weighs two hundred and fifty tons. It is operated by independent engines, as shown, for driving the rolls and adjusting their position. Two heavy pinching- and feeding-rolls are thirty-two inches in diameter, the bending-rolls being twenty-five and a half inches thick. Graduated index-scales are provided to show the operator just how his rolls are set. The machine is designed to rest on masonry below the floor surface, so that the plates can be run in from the level of a low truck.

Very similar machines are made for straightening plates of metal. In these more rolls are used, ordinarily seven. The rolls are made of forged steel, and are particularly useful in straightening boiler-plate or for tank- or safe-plates.

For forging, trip-hammers are used if the work is small. For large forgings the steam-hammer is the tool that is never likely to be superseded. It has been considerably improved since the days of Naysmith, the inventor. There are two types of direct-acting steam-hammers now made, —one in which the weight of the falling mass is concentrated in a head, or which works between guiding surfaces, and is connected by a piston-rod of relatively small diameter with the steam-piston in a cylinder situated above it. The other type, known as the Morrison, arranges the falling mass in the form of a heavy cylindrical bar, of which

the piston is an integral part, and is situated near the centre of the length, so that the bar extends above the piston and passes through the upper cylinder-head. The latter style is generally preferred, as the bar is better able to withstand the shocks of concussion than a piston-rod. In the smaller sizes the mechanism is supported on a single bent column. In the larger sizes the falling-bar operates between two stupendous supports.

FIG. 61.

WM. SELLERS & CO.'S TOOL-GRINDER.

The grinding of drills is very particular work, as, if improperly done, the holes made will not be uniform. Special

machines have been built to do this work, and one of them is here illustrated. It is supplied with a cooling stream of water, so that it is not necessary to draw the temper from the drills.

Such are a few of the more important machines used in the manufacture of other machines. Anything like a complete description of them would fill a work several times larger than this. As a rule, these machines are built better in America than abroad. Hiram S. Maxim, the inventor of the Maxim gun and flying-machine, himself an Englishman, has put himself on record as saying that this nation has the best mechanics in the world, and the man who investigates some of the large and excellently designed machine tools of the leading American makers is very apt to come to the same conclusion, whatever his nationality.

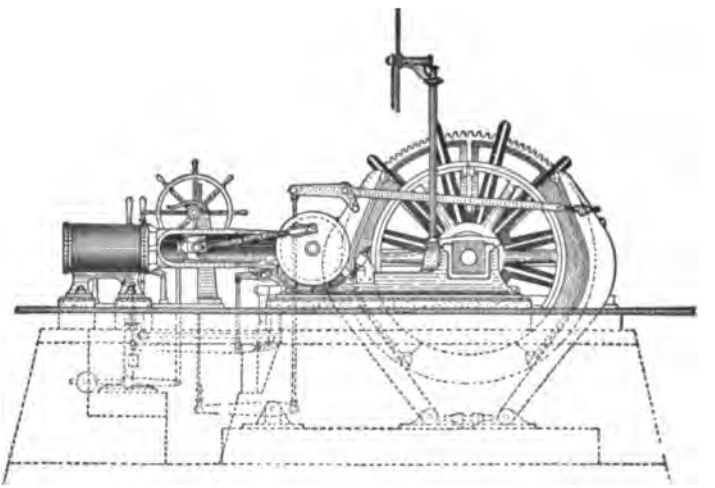
MINING AND MINING-MACHINERY.

Hoists, Drills, Compressors, and Safety Appliances—The Deepest Shaft in the World—Methods of Mine Timbering.

THE most important machine connected with a mine is the hoisting-engine, which is usually a combined steam-engine and hoist. There are two common styles. The Pennsylvania and Lake Superior mines mostly use hoists having very large drums, around which is wound, in spiral grooves, the wire rope that supports the cages. These are directly connected with the engines, and controlled by powerful brakes, usually of the band type, passing nearly around the large drum, on which they take hold by friction. An objection to this type is that the drums are necessarily heavy, and acquire a momentum like a fly-

wheel, which renders them hard to stop and slow in starting. The other style, more used in the Western States, makes use of a comparatively light reel and a flat rope, arranged to wind over and over on itself within a small space, so as to avoid the fly-wheel effect as far as possible.

FIG. 62.



A MINE REEL-HOISTING ENGINE.

In the larger plants air-brakes are made use of, very similar in construction to those employed on railway trains. In making calculations for mine-hoists the length of rope is an important factor. A depth of three thousand feet will require a size and weight of rope different from that in a fifteen-hundred-foot mine, where the hoisting capacity is to be the same. For a depth of two thousand five hundred feet the size of flat steel rope required would be five by three-eighths inches, with engine cylinders twenty inches long and with sixty inches stroke. For a depth of six hundred feet the rope would be required to be only half

the size to carry the same load, and the engines of less than half the capacity. It is hard to say what a mine-cage usually weighs, as there is so much variation in size. Perhaps twelve hundred pounds would be a fair average. The shafts of deep mines are commonly small, four by four and a half feet being a common size. The ordinary cage is a simple platform connected by two uprights with a cross-piece. There are stout iron braces, and the supporting rope is so hung that its breaking will release a spring that throws out clutches, engaging the guides, and preventing the fall of the cage.

Many other safety devices are in use. One of them is the electrical chair-indicator, for showing the engineer at the surface the position of the various chairs or landing-dogs at the levels. These chairs are devices for stopping and supporting a mine-cage in an upright shaft at a point opposite a level, so that men or material may be conveniently transferred from shaft to level, or *vice versa*. It is necessary that the engineer should know when these chairs are open so that a cage can go by, or when they are closed for its reception at a particular point. If he does not know, a collision may result. The old way of keeping the engineer informed was by means of wires, bell-cranks, and indicators. But as wires get bent, and lengthen and shorten with changes in temperature, they were not absolutely reliable. Connection by electricity has been found to be more certain. That in use at the Drum Lummon mine has returned eight hundred thousand indications to the engineer without error or failure in a single case. The indicator used with this device shows the engineer just where the cage is, so that he cannot drop the cage upon a chair because he may have happened to forget what level he is hoisting from, and if chairs are shifted carelessly or

with malicious intent he is informed of the fact. If a wire should in any manner become broken or disconnected, a danger signal is hoisted, and chance of disaster averted.

The mine-levels are supplied with tracks of very narrow gauge, seventeen to thirty-six inches, the commoner width being eighteen inches. Man-power, mule-power, steam, and electricity are used as means of propelling these. The smoke of the steam-locomotive is an annoyance, of course; but as blowers and air-compressors are in constant use, purifying and changing the air, it does not matter much, and mine-owners have been slow in adopting the little electric trolley locomotives that have been invented for their use.

For the carrying of ores down a mountain-side to the mill at the foot, or for transporting material up again to the mouth of the mine, wire tramways or aerial railways are much used. They are cheaper to erect than any other form of railway over a rough country, and they carry loads of half a ton at a time most economically. The double rope system is most in favor. The supports may be made of timber hewn on the spot, and they are not necessarily close together. Spans of a thousand feet have been built and operated successfully. The material carried up to the mine—"back freight," as it is called—is hauled up by descending loads of ore, etc., so that the work on the engines and the coal consumption are materially lessened, being required only to regulate the load.

Shaft No. 3, of the Tamarack copper mine, in the Lake Superior mining district, State of Michigan, is believed to be the deepest in the world. In August, 1894, it reached a depth of four thousand two hundred feet, and it is designed to carry it down below the mile limit in 1896. There are two other shafts belonging to this mine, each of

which is over three thousand feet, and a fourth shaft is designed eventually to go deeper than Shaft No. 3. The first shaft of this mine was sunk on faith to a depth of two thousand two hundred and seventy feet, or nearly half a mile, before the expected lode was struck. It is located near the famous Calumet and Hecla mine, where the vein of ore is remarkably rich and wide, and of regular dip. It was calculated that, if this vein held its course, the projectors of the Tamarack mine would strike it at two thousand two hundred and fifty feet. They took the chances and sunk a shaft, not a bored hole put down to test the presence of copper below, but a full-sized mine-shaft, suitable for a large business. The vein proved straight, and was struck within twenty feet of the point calculated upon. The shafts are sunk vertically until they reach the vein of copper ore, at which point they are inclined to follow the vein. The trip down No. 3 shaft occupies almost five minutes, and is accomplished in a cage hung from a drum-hoist. When there are no men in the cage the speed is doubled, as fast working is necessary to get up the ore. The miners below drill the rock with compressed air drills, the air being forced down through three-quarters of a mile of tubing by means of compressors. When a sufficient number of holes are drilled a blast is made, and, as soon as the gases dissipate, men are set to work gathering the ore into the cars, while another gang goes on drilling. Shaft No. 3 was sunk first through fifteen feet of drift, then a hundred feet or more of trap-rock, then through several seams of amygdaloid rock, which is full of small cavities. In many mines these cavities are more or less filled with pure metal, but here there is no copper until the conglomerate vein, composed of fragments of pre-existing rocks, is struck. The ore hoisted from the

shafts is carried seventy-five feet above the surface, to concentration works, where it passes through a series of crushers, etc. For a description of these see the chapter on ore-crushing machinery.

FIG. 63.

ROCK-DRILLING.

The timbering of mines constitutes an important part of mine-engineering. It is especially difficult in "swelling ground," as the miners term it, that tends to bulge into the shafts, or in loose, watery ground, or in quicksand. There are cases where mines have been abandoned as unprofitable because of these annoyances. The shafts

on the Comstock, and in Calaveras and Amador Counties, California, also at Leadville, Colorado, were difficult in the extreme, and reflect great credit on the engineers. The size of timbering in shafts varies all the way from eight by eight to twenty by twenty-four, or even larger. Inclined shafts require heavier timbers than vertical shafts, as they have to support a part of the weight as well as the thrust of the ground. Very stout wall-plates are used, and joints are made by mortising. Pumping and manway compartments do not require lining as a rule, but hoisting compartments, where cages are run, should be lined throughout to prevent accidents to the men, who sometimes, through crowding or carelessness, lean beyond the limits of the cage. All shafts are or should be provided with ladder-ways for use in case of accident to the hoisting mechanism.

In sinking large shafts it is sometimes necessary, if the ground is wet or soft, to drive lagging or planks ahead by the system called forepoling. This has the double advantage of retaining the sides in good shape and of keeping the ground in which the work is done better than it otherwise would be, as the planks confine the water. Thus the ground is more easily worked. In practice it is found better to keep one side several feet in advance of the other.

Where the ground is very loose and shifting it sometimes becomes necessary to make use of iron caissons to maintain the work. In watery ground a double thickness of planks with a lining of two or more inches of clay between is sometimes satisfactory. This is arranged in box form something like a caisson. Within a few years a patented process has come into use for freezing the ground at such points until the work has been carried by. The air-

compressors of a mining plant form a convenient means of supplying a temporary refrigeration at any desired point, as will be understood by any one reading the chapter on ice-making machinery, where the principle of artificial cold is explained.

Mine-shafts are now almost invariably made rectangular in section. L forms are not in favor, and circular ones have gone out of date. Of course the circular form is well calculated to sustain itself, but the rectangular is much more convenient for the arrangement of compartments, guides, etc.

In shafts it is very necessary that the upright timbers of the guides for the cage should be very neatly joined, so that there may be no jamming or danger from warping. Such joints are best made by means of a tongue and groove fastened with log-bolts, though lap-joints are much used.

The principle to be borne in mind in mine-timbering is that heavy beams should be set continuously in rectangular form. If we have an inclined shaft six feet wide, the cross timbers are best placed at six-foot distances, the timbering forming the outlines of a succession of cubes. Timber is usually squared before coming into the mine, but occasionally round timber has been preferred, as at the Utica-Stickles mine, Calaveras County, California. Here the gold-bearing rock is forty to a hundred feet wide, and about four hundred feet high, necessitating its being stoped —that is, worked by steps. The round timbers are all cut into eight-foot lengths, and set up staircase-fashion as the work progresses. The management buy the thickest timbers they can get, with the result that they weigh all the way from seven hundred pounds to ten or twelve hundred, and in a few cases sixteen hundred pounds. The handling of these becomes quite a business. They are

usually lashed together, and sent down the shaft in or attached to a stout iron bucket called a skip, and at the levels are transferred to small flat-cars, called trolleys, specially built for hauling them. Two men and a lot of eight-foot chains constitute an equipment for sending down the timbers. These chains bear hooks and rings, and with them the timbers are securely fastened in the skip. At the Utica mine, however, they hang them below the skip, and thus are able to make quicker work of it; but this method cannot be used where the shaft departs much from the vertical. Winzes, or minor upright passages connecting levels, are very convenient in handling timbers, affording opportunities for lowering them at convenient points.

At the diamond mines of South Africa suitable timber is not obtainable, and it is imported all the way from the Baltic Sea, or sometimes from California. This is expensive, but as they occasionally find down there diamonds of three or four hundred carats, the stockholders can afford to pay big freight charges on timber.

ORE-CONCENTRATING MACHINERY.

The Mechanisms in Present Use for removing the Less Valuable Portions of Ore, with some Hints as to Gold and Silver Milling.

ORE comes from the mine in all shapes and sizes, just as it happens to be broken up, and the first process in its treatment is to render it more uniformly fine. For this purpose it is dumped on a great screen of iron bars, called a grizzly, the bars being so inclined that the coarse material is slid off to a crusher, while that which is already

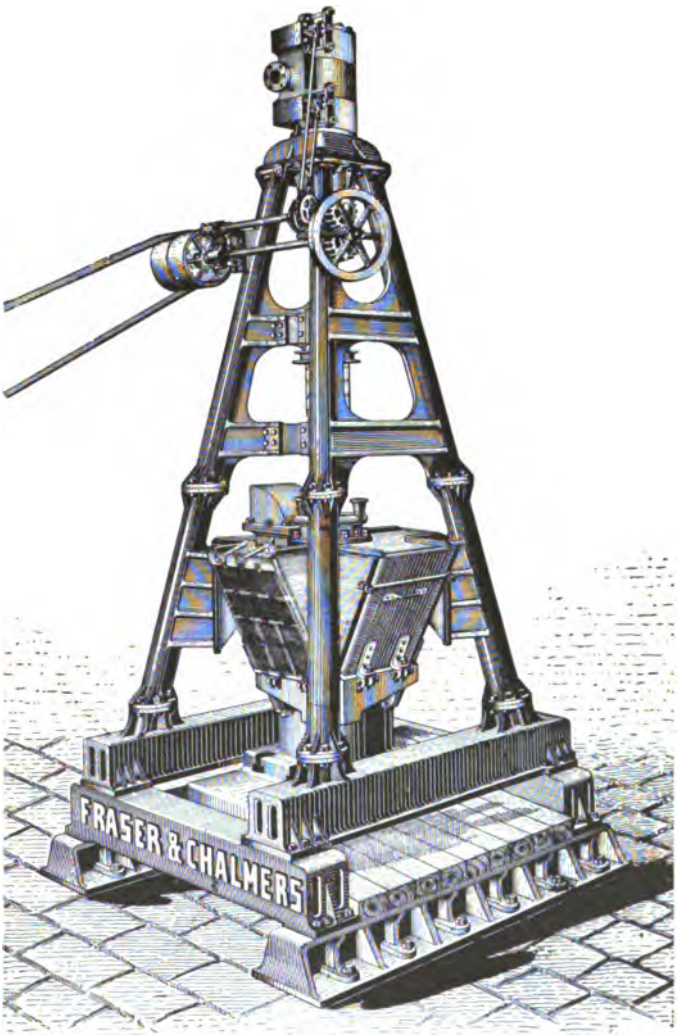
sufficiently fine falls through into a bin, which later receives the ore from the crusher. One of the best known forms of crusher is the Blake, which has moving jaws of enormous strength, that open and close with a motion that lets down a little rock at a time, and drops it through as soon as it is sufficiently small. When set to crush not over an inch and a half in size, a large crusher will dispose of about seven cubic yards of rock per hour. The Dodge crusher is a very similar machine, but is suited to finer crushing. It is especially adapted to preparing ores for the Huntington mill, which is described farther on. Gyratory crushers are also made, of which the Comet crusher is the best known. It is serviceable where large capacity is desired in a particular place, and has been installed in the famous De Beers South African diamond mines and also in some gold mines.

If the ore handled is gold and is to be treated by a wet milling process, it goes from the crusher-bin to an automatic feeder to be fed directly to the stamps, etc. The Tulloch automatic ore-feeder is a common form, consisting of a hopper-like box, below which is an oscillating tray of wrought iron. The back of the hopper has an adjustable scraper, and at each motion of the tray a portion of the ore is scraped forward to the stamp-battery. The Challenge ore-feeder is especially adapted to wet ores. It has a circular bottom-plate, set at an angle so as to bring down the ore as it rotates.

If the ore handled is silver, and it is to be treated by the dry process or by roasting, a revolving dryer is placed below the crusher, so that it may be thoroughly dried before being subjected to a finer crushing.

The ore-stamp as commonly made is a very simple machine, consisting of a heavy upright rod, with a stamp or

FIG. 64.



A STEAM-STAMP.

pounder on the lower end, and a projection by which it may be raised by a cam on a rotating shaft, so as to fall by gravity. They are set up five or ten in a frame, and often a whole row of frames, together constituting a stamp-battery. This primitive mechanism is giving way rapidly to the steam-stamp, which is designed somewhat after the manner of a steam-hammer. This machine is pyramidal in form, having four principal columns that meet in a ring at the top and rest in heavy cast-iron sills at the base. Surmounting the top ring is a steam-cylinder set vertically, so that the descending piston can be used to raise and lower the powerful stamp. Within the four columns, at the base, is a large mortar, resting on a heavy cast-iron bed-plate or anvil twenty inches in thickness, and weighing about eleven tons, this in turn being supported by a row of stout wooden sills, designed to spring when the blow is delivered. Between the anvil and the springy timber is a rubber cushion an inch thick, which assists further in reducing the jar. The piston of the cylinder and the stamp-stem are connected by a disk, and between the two, in the junction piece, is another piece of rubber to prevent too great jar of the steam-cylinder. Ore and water are fed in at the top of the mortar, the water being continually thrown against the sides of the stamp-stem to keep it from being scored and cut to pieces by the sharp sand. The largest size of these stamps has a stroke of thirty inches, and its capacity is about one hundred and fifty tons of fine crushing per day of twenty-four hours, or two hundred and thirty tons of coarse crushing in the same time. This enormous machine stands about thirty feet high, and weighs seventy tons. It will do the work of about seventy-five of the old-fashioned stamps.

The old stamp-battery continues to have its adherents

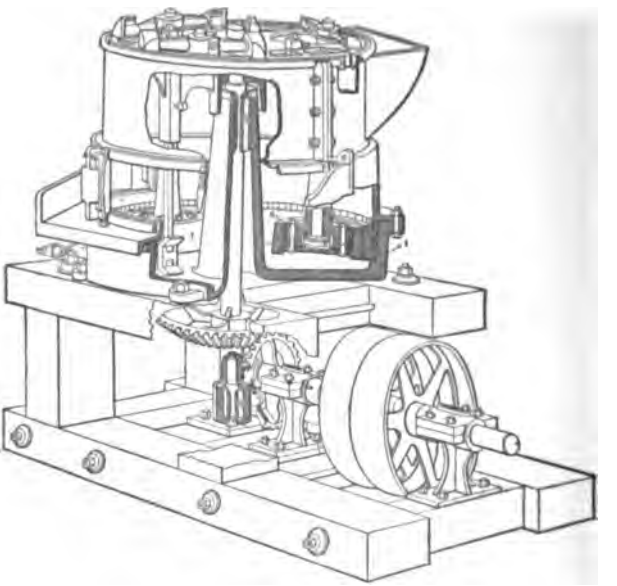
for fine crushing, and in some cases fast-running rolls are preferred in place of stamps, but this depends upon a particular ore, as upon an extremely hard ore the wear and tear upon the rollers is liable to prove expensive, and the additional machinery required by fine crushing dry with rolls adds to the expense of erection and running, and also the wear and tear. With these rolls a system of revolving screens is generally used, and various elevators to turn the material back to the rolls for recrushing, and usually it is necessary to maintain several sizes of rolls.

Crushing rolls are employed on either wet or dry ore, where it is desired to granulate the material and avoid the pulverizing action of stamps that produces slimes. The common form is known as the Cornish geared crushing-rolls, and consists of a pair of heavy iron rollers, as much as eighteen inches in diameter in the larger sizes, and rotating oppositely to draw in the ore. One roll is set in spring bearings to avoid danger of breakage if the pressure rises above a certain point. Removable steel faces are used on the rolls that can be replaced when they are worn out. During recent years they have been improved in construction, so that they do faster work, and a complete machine has an automatic feeder that carries the ore regularly across its face. For certain classes of work there has been a demand of late for the belt-driven class of rolls, operating entirely without geared connections between the crushing shafts, which are independently driven by belts run on large pulleys. The speed is higher, and the belts do not wear out as fast as the gears, which are subject to severe friction.

Under some circumstances complete pulverization of the ore is desired, and for this purpose no machine has been as successful as the Huntington mill. This makes use of

upright rolls, having an oiled bearing above, away from the grit and slime, and no bearings at all below, as the rolls run around on a horizontal steel tire. This arrangement gives the mill great wearing qualities, not possible in any mill where the slimes have a chance to work into the bearing. The accompanying illustration shows the

FIG. 65.



THE HUNTINGTON MILL.

operation of the Huntington mill, as built by Fraser & Chalmers. The ore and water are both received at the hopper on the right. The rotating rolls, 7 and 9, throw the ore against the ring-die 1, being kept to their work of crushing by the centrifugal force. Complete pulverization

can be obtained. It will be observed that the only oiled bearings are on the three shafts, set in the upper frame. The lower surface and the weight of the rolls all assist in the pulverization, giving most economical results. The ends of a screen are shown in the part broken away, and through this the water and pulverized ore find exit, no ore being permitted to escape until of the required fineness of the screen. The discharge is so perfect that very little slime results, the pulp being in good condition for concentration.

One more crushing machine should be mentioned before closing the subject. It is the Sturtevant mill, which has been borrowed from the cement-makers. It has been found very useful for coarse crushing, and has a peculiar action. There are two cylindrical heads rotating in opposite directions within a screen-lined casing. The heads become filled with a conical lining of the material to be crushed, and these, by centrifugal force, throw the ore which falls on them against the pieces thrown in the opposite direction by the other head. In this way the material is broken against itself without scoring or abrading the mill. To prove that the theory of the machine is correct, balls of the hardest white cast iron have been introduced and thrown around until they smashed themselves against each other, the mill being uninjured. As a preparatory machine, combining the duties of the rock-breaker and coarse roller in one operation, this mill is being used by many smelting-works.

Jigs or jigging machines are used to separate the ore in imitation of the shaking of a sieve by hand under water. The ordinary type of jig consists of a water-tank divided by a partition above, not reaching the bottom. On one side of the partition is fixed a horizontal screen on which

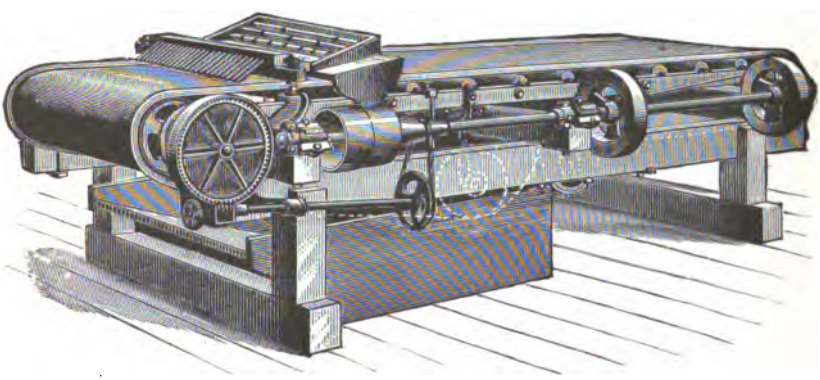
the sized ore is fed, and on the other side a loosely working plunger is operated vertically by a crank or the like. The reciprocating or up-and-down motion of this plunger causes a regular pulsation of water through the screen, shaking and agitating the ore so that the heavier particles settle down and either come through the screen or are worked through a gate above the screen-level, while the lighter particles of rock move on horizontally and discharge over the side or end of the screen. Jigging machinery is usually employed for coarse material, and operates on the principle that a mixture of ore particles varying in weight, because some contain more metal than others, tend to arrange themselves in layers when shaken, as by a pulsating column of water. Jigs are made with as many as four compartments, the larger number being required when more than two products are desired. In the case of three- or four-compartment jigs, the plungers are regulated as to stroke and speed independently of each other and with reference to the work to be done respectively on the screen-beds they govern. It is usual to depress the plungers by means of a tappet or eccentric, and throw them up with a metal spring as they are released.

An hydraulic separator is manufactured which consists of a V-shaped trough, into which the pulp flows through a smaller trough, or launder, while the slimes are discharged by overflow through another trough. A partition or diving board is set down into the principal trough to prevent any direct flow from the entrance to exit. A stream of clean water is forced in near the bottom under sufficient pressure to drive the slimes and mud to the surface, where they are discharged at the overflow, while the heavier particles and clean water are discharged below.

Another form of separator is known as the Calumet classifier, and consists of a trough having four or five depressions along the bottom. The water and sand undergo successive washings in each depression as they pass along. Shields are used to guard the depressions, which retain the heavier particles. This form is said to use very little water as compared with other separators.

In a general concentrating plant separate settling-boxes are used to divide the slimes for dressing or fine concentration, but in a distinctively fine concentration mill the ore is at once reduced to pulp for treatment. In this case buddles and tables of different types are used where the product is of various grades, some requiring further treatment, but for clean concentration the Frue vanner is universally used. Where gold and silver are the metals sought the ore requires fine crushing, and the same is true

FIG. 66.



THE FRUE VANNING MACHINE.

in a less degree of lead, copper, and tin ores. For such, stamps and Frue vanners are the regulation outfit, the vanners producing a cleaner mineral than other slime-

dressing machines, with exceptionally low loss. They also have the advantage of immediate automatic treatment of the pulp without sizing, at one operation, and without any rehandling. They require a minimum of power, water, and attendance.

The Frue vanner has an endless rubber belt presenting a top surface twelve feet long and four feet wide, supported by rollers so as to form an inclined plane bounded on the sides by rubber flanges. By means of a drum the belt is given an upward travel along the incline, and at the same time receives a regular shaking or settling motion from a crank-shaft running along one side at right angles to the travel of the belt. At the head of the belt is arranged a row of jets of water, while the ore is fed upon the belt in a stream of water about three feet from the head, and flows down the incline slowly, the constant shaking depositing the mineral on the belt so that it is carried upward. The water-jet washes back the light sand, allowing only the heavy mineral to pass to the water-tank below. The Embrey ore concentrator is a very similar machine, having an end shake instead of a side shake.

The revolving buddle or slime-table is a very useful machine for separating ores. The revolving Evans's table is perhaps the best-known type. It has a circular table about fourteen feet in diameter that is slightly coned. The ore is fed to this from the centre, along with the water. The rotation of the table carries around the deposited material, which is subjected to the washing action of clear water flowing down from the centre, and is eventually washed off the table by strong jets of water, sometimes assisted by stationary brushes if water is scarce, and dropped into launders below. The table thus continuously arrives clean to receive the flow of pulp, being freed of

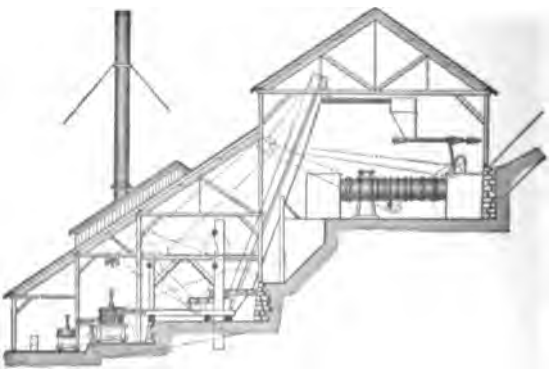
waste, middlings, and clean mineral before the full rotation is completed. The surface of the table is commonly made of soft pine wood, but cement and rubber are also used. Another form of this machine has the cone inverted, receiving the ore at the outer edge, and discharging at the lowest point, the centre. In yet another form the buddle or table is stationary, the feed-spout and washing pipes doing the travelling, the effect being precisely the same. Within a few years a double or two-story slime-table has been introduced which gives better results, though with any slime-table it is necessary to partially classify the material, in the first place, as by an hydraulic classifier. The Evans's slime-table will handle about twenty-five tons of material per day of twenty-four hours. The rotation is of necessity comparatively slow, one complete turn being made every eighty seconds.

The percussion-table is a sort of compromise between a vanner and a revolving buddle. It is much used in Germany in place of the latter machine. It has an inclined table—or, more commonly, several such tables—made of wood, rubber, slate, stone, or even plate-glass. This table is usually about four by eight feet in surface, and is regularly shocked or jarred by a cam and spring operating alternately against the frame. The ore is fed over the surface with a stream of water from one of the upper corners. The downward motion of the current of water combined with the side-jarring of the table tend to work the heavier particles along in a diagonal course, so that the grades may be separated by guides.

The various processes used in obtaining metals from the ore are too numerous and exhaustive to be more than hinted at here. For the milling of silver ores the Boss continuous process of amalgamation, patented by M. P. Boss, has come

into extensive use within a few years. It is undoubtedly superior in many respects to the old system of pan amalgamation. The first cost of plant is also considerably reduced. The illustration shows a cross-section of a silver-mill as arranged for this process by Fraser & Chalmers.

FIG. 67.



CROSS-SECTION OF A SILVER-MILL.

The ore passes through the grizzly and crusher, on the right and upper end of the picture, in the usual manner, and by means of the automatic feeders to the stamps in the centre. The pulp from the stamp-battery is flowed through pipes to special grinding pans, on the next to the lowest elevation, thence by other pipes to the first amalgamating-pan, and continuously through a line of pans and settlers on the lower floor, the tailings being run off or led over concentrators. The quicksilver—necessary to draw the particles of silver into contact—is let into the pans by means of pipes from a distributing tank, and the amalgam so formed is flowed through pipes to a strainer. The chemicals are supplied to the pans by two automatic feeders. Steam-siphons are used for cleaning out the pans

and for carrying the pulp past any pan when it is necessary to cut it out for repairs. The main line shaft runs directly under the pans and settlers, each of which is driven from it by a friction-clutch. The arrangement of separate clutches is made for the purpose of enabling any pan or settler to be stopped or cleaned without stopping the whole line.

The largest quartz-mill in the world is believed to be that of the Alaska Treadwell Gold-Mining Company, at Douglas Island, Alaska. Here are run two hundred and forty stamps of eight hundred and fifty pounds each, six rock-breakers, and ninety-six concentrators, with a capacity of six hundred tons of ore per day of twenty-four hours. The mill was erected by the Risdon Iron Works of San Francisco. Here the gold ores are treated in vats by the chlorination process, which is based upon the property of chlorine gas for transforming metallic gold into a soluble chloride of gold. In this condition it can be dissolved in cold water and precipitated in a metallic state by a solution of sulphide of iron, or as a sulphide of gold by sulphuretted hydrogen gas, this method being known as the Plattner process. The sulphurets, as the gold-bearing pyrites are called, are collected at the mill on Frue vanners, and contain, on an average, forty per cent. of sulphur. The gangue is quartzose, with a little calcite, on account of which it is necessary to roast with salt. Four reverberatory furnaces are used for the roasting, and each is a monster of its kind, being thirteen feet wide and sixty-five feet long. The four have a total capacity of twenty tons of sulphurets daily. When the roasting is completed, the charge is removed from the pit under the furnace, and spread on the cooling-floors, sufficiently moistened to prevent dusting and packing, and carefully sifted into large vats. The lids of the vats are then lowered, the joints

carefully cemented with clay, and the chlorine gas turned on. Four hours are sufficient for the gas to permeate the material, after which the gas is shut off and the vats are allowed to stand for about thirty hours. The leaching requires twelve hours. The tailings are sampled and assayed, and if found to be worth less than three dollars per set of vats they are allowed to run to waste. For convenience and safety the gold is run into intermediate tanks, and from these into precipitating vats. When a vat is full, or all the solution is run in, the pulp is stirred and allowed to settle for from eighteen to twenty-four hours. The supernatant liquor, containing such gold as has not been precipitated, is then drawn off through a large filter, which gathers the remainder, amounting to only twenty-five cents' worth for each ton of material that has been treated. A clean-up is made twice a month, at which time all the gold is washed into a small tub, in which it is allowed to settle all night, when the supernatant liquor is drawn off and returned to one of the precipitating vats. The gold in the small tub is then placed in an iron drying-pan, where it is gently annealed over a small stove, taken into the melting-room and run into bars. The drying and melting of twelve thousand dollars' worth of gold can thus be accomplished in a single day by one man.

In the Black Hills Mills battery amalgamation is used to extract the gold. It begins in the mortar, where mercury is added at intervals, and ends on the apron-plates, where nearly all the amalgam not retained by the inside amalgamated copper plates is collected daily, any deficiency in the collecting mercury and amalgam on the plates being supplemented by the various traps.

THE PELTON WATER-WHEEL.

A Simple Machine which has attained Marvellous Results, by a Return to First Principles—A Steam Turbine similarly constructed.

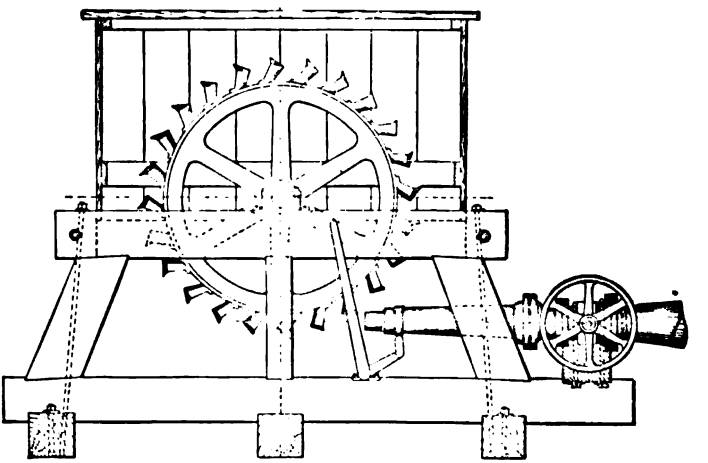
THE use of a fall of water to develop power to do work dates from such an early period as to be lost in myths. No doubt this was the very first power which man harnessed to his primitive machines. As long as Nature continues to draw the moisture from the seas, and drop it in the form of rain upon the mountain-tops so that the rivulets are formed and combine to make mighty rivers, so long shall we have water-power; and as long as such power exists it is likely to be used, for it is the simplest and least expensive natural source.

Considering these things, it is a little surprising to learn that only five per cent. of the water-power of the world has been rendered available for use. Only at the present time, 1895, is the great Niagara Fall, the mightiest natural power of the sort on the globe, about to be utilized for man's benefit.

A more widespread form of neglect as regards water-powers has been in the overlooking of the advantages of small streams of great fall, the tendency having been to develop and use only large streams with a low head or fall of water. When we observe the cumbersome mechanism required to use the power of a large river of slight fall—the great dam and monstrous turbines, with huge pipes and shafting—and contrast these with very simple means devised within a few years for using the water of small streams having a high head, we are filled with wonder as to why somebody did not think of this before. The Pelton system of water-power, to which the world is indebted

for a means of producing great forces from little streams, makes use of not only the very simplest form of mechanism, but a form which assuredly was very like the first that man devised. It is amazing to think that the very simple water-wheel shown in the illustration was not put

Fig. 68.



THE PELTON WATER-WHEEL.

on the market three thousand years ago instead of some ten years since. It is simply a wheel with a ring of buckets on its periphery, driven by water from a pipe delivered through one or more nozzles at an angle. Yet this wheel received the highest award at the World's Columbian Exposition, as a recent invention of unusual merit. Under the high heads for which it is designed, it makes available almost the whole of the theoretical power —more, probably, than any other machine manufactured. The power of the Pelton wheel does not depend upon its diameter but upon the head and the amount of water

applied to it. Where a very considerable amount of power is wanted under a comparatively low head, a wheel of larger diameter is necessary to admit of buckets of corresponding capacity, as also the application of two or more nozzles, for the purpose of multiplying power. The smaller sizes are principally in demand, but wheels as large as fifteen or twenty feet in diameter are sometimes made for the purpose of direct connection to crank-shafts of pumps, compressors, etc. Small buckets are frequently used on wheels of large diameter for the purpose of reducing speed when operating under high heads and running slow speed machinery. More than one nozzle is sometimes used to increase the power by applying more water or for securing a higher speed than can be obtained from a larger wheel with a single nozzle. By using multiple nozzles sufficient power can often be obtained from a wheel of small diameter to admit of direct connection to the shaft of a dynamo or other high-speed machinery without intermediate gearing, or of giving such increase of speed as to admit of belting direct without the use of countershafts, etc.

The transmission of power by electricity has opened up a wider range for the utilization of such sources of power than has been possible by any previous methods, and the field is continually widening as the science advances. Water that for thousands of years has run to waste can now be transformed into electrical energy, and carried long distances and made as useful as at the point where generated, and at small cost in most cases as compared with steam. The immeasurably vast resources of power available by this means open up in all directions new fields for enterprise, affording profitable employment for both labor and capital.

It is under heads of fifty feet or more that the Pelton

wheel develops its advantages, and under heads of several hundred feet the power developed is simply enormous, and not to be obtained from any other form of wheel. Let us look at the figures: A twelve-inch wheel run under a twenty-foot fall develops only one-eighth of a horse-power. Give it a hundred feet of fall and we secure nearly one and a half horse-power; make it two hundred feet fall, and we have four horse-power; while at five hundred feet, we get sixteen horse-power; and at a thousand feet, fifty-two horse-power. This is a tremendous power for so small a wheel, but if you want fifty horse-power, and have but eighty feet of fall, use a six-foot wheel and you get it. At a head of two hundred and fifty feet your six-foot wheel will give you two hundred and sixty-seven horse-power; at five hundred feet, seven hundred and fifty-five horse-power; while at one thousand feet you will receive the enormous power of twenty-one hundred and thirty-six horses—all from a six-foot wheel that one horse could carry without trouble. All these figures are given on the basis of one nozzle. If the figures are not high enough, put on three or four more nozzles, and you can get any power you want.

One of the most notable features of the Pelton system is the facility with which adaptation can be made to widely different conditions of water-supply and power without loss of useful effect. This is accomplished by a simple change of nozzle-tip, varying the size of the stream thrown on the wheel—the power of which may be varied by this means from its maximum down to twenty-five per cent. without appreciable loss—thus working to its full capacity with an ample water supply, or to the same relative advantage with a reduced quantity, when for any reason the supply fails in part. This system also admits of using,

without disadvantage, a wheel of larger capacity than present wants require with reference to an increase of power when wanted. Variations of construction as to diameter of wheel, size of buckets, number of streams applied, also admit of adaptation to all conditions and requirements of service either as to speed or power, in the most simple and efficient way, and at the smallest possible cost.

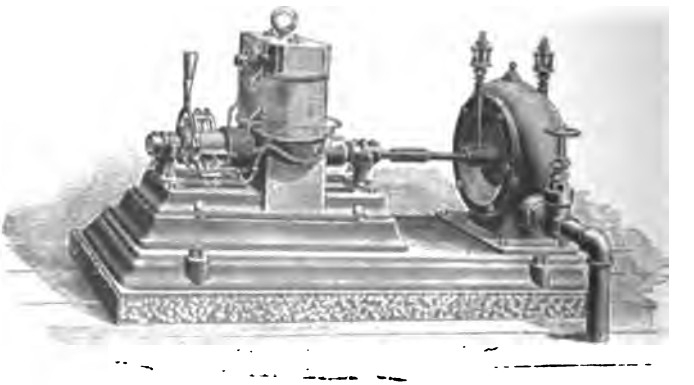
At the Comstock mines in Virginia, Nevada, there is a Pelton wheel, of three feet diameter, that develops more power than any other contrivance of its size in practical use in the world. It is made excessively strong, being a solid steel disk with phosphor-bronze buckets securely riveted to the rim. It is located at the Sutro tunnel level of the California and Consolidated Virginia shaft, sixteen hundred and forty feet below the surface. In addition to the head afforded by the depth of the shaft, the pipe is connected to the line of the Gold Hill Water Company, which carries a head of four hundred and sixty feet, giving the wheel a vertical head of two thousand one hundred feet, equivalent to a pressure of nine hundred and eleven pounds. The water, after passing the wheel, is carried out through the tunnel, four miles in length. The wheel makes eleven hundred and fifty revolutions a minute, giving it a peripheral velocity of a hundred and twenty miles an hour. If it ran without load it could be speeded to just double these figures, giving the rim a speed of twenty-one thousand six hundred and eight feet per minute, or two hundred and forty miles an hour. With a half-inch stream of water it develops one hundred horse-power. This wheel has run several years under these conditions without any cost for repairs.

The Hydraulic Power Company, of Chester, England, run wheels under nearly as severe pressures. They have

an eighteen-inch wheel, weighing but thirty pounds, that gives twenty-one horse-power with a quarter-inch stream.

The Pelton wheels are also built for use in cities as motors, having for this purpose an iron case, with a pipe bringing in water from the mains. They are very desirable where the pressure is high, and may be conveniently connected with a dynamo, as shown in the illustration. The

FIG. 69.



THE PELTON MOTOR WITH DYNAMO CONNECTED.

wheel, under these circumstances, is made of a diameter to give proper speed to the dynamo under the water-head available. Where a considerable head of water is obtainable, a small stream may be used to run an electric lighting plant at small cost. The water being free, the only charge is for interest, repairs, and attendance.

Right in line with this discovery of the virtues of the simple form of water-wheel here described comes an invention for using steam in the same manner. No doubt the first endeavor to use steam was by allowing it to blow a draft in a rotating fan or wheel of some sort, but the

power thus developed in the early experiments did not compare with that obtained by using steam under pressure through the medium of a cylinder, as in the steam-engine. In 1890, Dr. Gustaf de Laval made a little wheel designed to rotate fast enough to secure the full force of escaping steam. It was a miniature turbine wheel, of less than four inches diameter, constructed in the most substantial manner of steel and aluminum bronze, and arranged to admit steam through its axle and deliver it at the periphery, after having served to do work by impinging on the inner guides of the wheel. He secured a rotation of fifty times a second, developing five horse-power with this insignificantly small contrivance. This wheel was exhibited at the Columbian Exposition, where it attracted much attention. A larger size—of about seven inches diameter—developed twenty horse-power. The only difficulty would appear to be the utilization of such a speed without enormous frictional losses in reducing the speed to common necessities. For this purpose De Laval devised gear-wheels rotating in oil, but it is fair to presume that he was not wholly successful, since the steam-turbine, as he calls it, has not been placed upon the market. If it can be made to deliver its power economically there will surely be a great demand, because of the economy of first cost and of space in using such a device in place of an ordinary engine.

ILLUMINATING GAS.

How Coal-Gas was made, how it is made and enriched, and how it is likely to give way to the New Illuminant, Acetylene Gas.

FEW people have any clear idea as to how the illuminating gas which they burn is manufactured. In a general way they know that a gas company somehow extracts vapor

from coal and gathers it in a big tank or holder for distribution. If they look up the matter in the encyclopædias they gain some notion of the methods and principles, but little of the latest and newest processes that have come in within a very few years, displacing older methods because they are better.

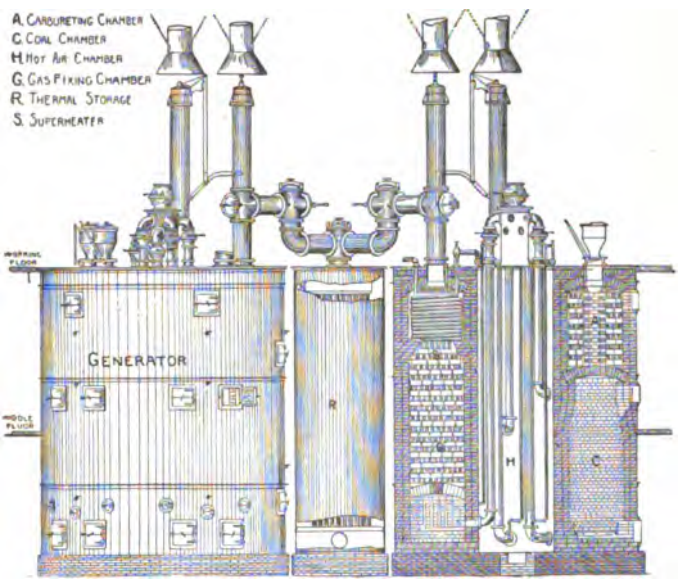
The principle of making coal-gas consists in heating the coal in a large metal or fire-clay vessel, called a retort, so as to distil off the gas. By this simple process a ton of coal used in a retort will yield about ten thousand cubic feet of illuminating gas. A vast improvement on this process is obtained by taking the coal used in the first operation, which has now become coke, heating it to incandescence, and forcing steam through the mass. By this means about thirty thousand more feet of gas are obtained from the ton of coal, not including such coal as is used for the fires producing the heat. The gas produced by this process, in which steam is used, is called water-gas, since it is the decomposition of the water that releases the hydrogen forming the gas. A vapor made from crude oil is commonly added in small quantities to give greater illuminating power.

Carbon when highly heated has so much affinity for oxygen that it will decompose steam in order to combine with the oxygen that forms a part of the steam. This is the principle that makes water-gas possible. Either anthracite coal or coke may be used to secure the necessary carbon.

There are a number of recently perfected processes in use for making a rich gas economically, and a description of the Rose-Hastings process will serve as well as any other, for they are much alike. This is a combination process for making coal-gas, water-gas, and oil-gas at the same

time, and securing the benefits of a desirable combination. It is much used in connection with natural-gas plants, which have a bad habit of giving out as the thermometer approaches zero, hence require to be supplemented by a system of manufactured gas. This apparatus consists of one or more heating chambers or retorts, used for the distillation of soft coal into gas; also chambers for coke, carbu-

FIG. 70.



THE ROSE-HASTINGS COAL-GAS APPARATUS.

retting, gas-fixing, and steaming, all arranged in a circle; and a central chamber for distributing hot air—the whole set of chambers being enclosed in a great steel shell, as shown in the illustration. The sections for soft coal and coke are arched midway of their height with perforated divisions, the chambers above the arches being respectively for

storing heat and for carburetting, the latter being the process of impregnating the gas with carbon to increase its illuminating power. The heat-storing and carburetting chambers communicate near the top, and the coke and gas-fixing sections near the bottom. The chambers using coal have mechanical feeders by which the coal can be supplied at any time. The coke chamber may be charged once or twice a day through the doors.

The coke and coal being supplied and the fires properly regulated, air is driven up through the coal chambers, burning a portion of the coal, and heating it to a high temperature. The hot gases so obtained are carried down through the coke, in this way heating without burning it. When the apparatus is brought to the right heat, and before the hot-air blast is stopped, a charge of soft coal is dumped into each of the coal chambers. The blast is then stopped and steam turned on under each of the coal chambers, and oil turned in at the top of the coke chamber. As a result water-gas is produced in each of the coal chambers, and, mingling with the coal-gas distilled off from the fresh charge of soft coal, passes over to the coke chamber, down through the red-hot coke, where it encounters and mixes with the vapors of crude oil, the whole forming a "fixed" gas—that is, a gas that will stand a low temperature without condensing. This combination secures the best results of three processes in one, combining a water-gas plant with a coal-gas plant and enriching the mixture with oil-gas. With this apparatus thirty-eight pounds of coal, thirteen pounds of coke, and three and a half gallons of oil will make one thousand cubic feet of twenty-two candle-power gas, including the coal consumed in heating the apparatus.

The gas leaves the machine at a temperature of about 800° F., which is above the melting-point of the softer

metals, as zinc and lead, and, when we consider how readily gas burns, it seems at first a dangerously high temperature. This hot gas passes through a multitubular condenser, so that it may heat the water for the boilers while cooling itself, thus effecting an economy. The condenser is usually so hot as actually to generate a considerable quantity of steam that goes over to the boilers with the feed-water. After leaving the condenser the gas passes through a seal and washer, an apparatus for removing impurities; and thence to the scrubber, where the condensable matter is got rid of; then to a purifier, and finally to a gas-holder, the great telescopic tank by which we always recognize a gas-works.

Gas made by the above process mixes readily with natural gas, and a first-rate article has the following analysis: hydrogen, 36.40; marsh-gas, 23.20; carbonic oxide, 19.10; heavy hydrocarbons (illuminants), 14.05; nitrogen, 3.08; carbonic acid, 3.02; oxygen, 1.15.

With apparatus now on the market, it is possible, in sections where coal is cheap, to sell gas at thirty-five cents per thousand feet, and this is actually done in Louisville, Kentucky. There are few places, however, where it sells for less than one dollar, though the tendency of prices is downward.

A very material cheapening in the use of gas for lighting is accomplished by placing a chemically-prepared hood over the gas-flame, producing incandescence of the whole hood, resulting in the development of four times as much light without increasing the gas consumption. Dr. Auer von Welsbach experimented with the salts of rare earths, until he found a combination that produced the above results. At first the discovery was of little commercial value, because of the scarcity of the earths, cerium, lanthanum,

thorium, yttrium, zirconium, praseodymium, neodymium, and erbium, but as soon as it was known that a commercial demand existed for them they were found in considerable quantities, in Henderson County, North Carolina, in Norway, in the Ural Mountains, in northern California, and in parts of Texas. These deposits have been promptly bought up by interested parties, and, as a result, the manufacture of the hoods is in a fair way to become a valuable monopoly. In manufacturing the hoods for the lights, the first process is to weave a cotton hood, which is then soaked in the salts obtained from the earths by various patented processes. After drying, the cotton is burned out, and the hood is ready for use. The light obtained by these incandescent hoods is so soft and powerful, and the amount of gas used is so small, that they are likely to supplant the incandescent electric light in many cases.

So much for coal-gas. It is possible, in spite of these marked improvements, that the world is on the point of discarding it altogether in favor of acetylene, for which the most astonishing claims are made, and apparently substantiated. This gas surpasses in brilliancy and economy all other forms of light, and would be likely to distance electricity were it not that the methods of manufacturing electric light are liable to great improvement in the next few years. Acetylene, when burned at the rate of six feet an hour, the pressure common to good gas-burners, emits a light equal to three hundred candle-power, as against twenty-two to twenty-seven candle-power for good qualities of enriched water-gas. That it is more than twelve times as valuable was demonstrated to an audience recently at the Franklin Institute in Philadelphia.

In order to understand what acetylene gas is we must first premise that a carbide is a compound of carbon with

one or more positive elements; that the carbides of the alkali and alkaline-earth metals, such as potassium, sodium, borium, strontium, and calcium, when brought into combination with water will decompose the same, forming a hydrated oxide of the metal and acetylene gas. In other words, the combination of calcium (lime) with carbon (charcoal) and with water can be made to produce a brilliantly-burning gas. Since these three things are exceedingly cheap, it remains only to find an economical method of manufacture, and we have a light and a fuel that will beat the world. Such a process is described in a United States patent granted to Edward N. Dickerson and Julius J. Suckert, March 19, 1895.

Calcium carbide, the principal constituent of this gas, as prepared by Thomas L. Willson, is a dark-brown, dense substance, having a crystalline metallic fracture of blue or brown appearance, and a specific gravity of 2.26, or a little less than charcoal. It has a peculiar odor, due to moisture in the atmosphere. It will withstand a very high temperature, a Bunsen blast-lamp raising it to a white heat without other effect than to convert the exterior into lime. When brought into contact with water, or water vapor that is not extremely hot, it is rapidly decomposed, one pound of calcium carbide forming nearly six feet of acetylene gas at the temperature of 64° F.

Acetylene gas is colorless, smells somewhat like garlic, and is very slightly lighter than the air. It may be heated to a temperature of 370° F., under a pressure of forty-three atmospheres, without decomposition. It can be condensed to a liquid with ease, the critical point of temperature, above which it will not liquefy, being about 100° F. One pound of the liquefied gas, when evaporated at 64° F., gives forth fourteen and one-half feet of gas at atmospheric

pressure; in other words, its bulk increases four hundred times.

Dr. J. J. Suckert thus describes a beautiful experiment with the gas:

"We will now show you the liquefied gas contained in this glass tube surrounded by a metal casing. As you will observe, the liquefied gas forms a colorless, mobile, highly refractive liquid, which, when the pressure is slightly relieved, commences to boil and evolves a gas which, ignited as it issues from this gas tip, burns with an intensely white flame. If the liquefied gas be suddenly relieved of its pressure, or allowed to escape in its liquefied state to the atmosphere, a portion evaporates rapidly, thereby abstracting from the remaining portion sufficient heat to solidify it. This tank, which is now shown you, contains liquefied acetylene, which has been cooled to a temperature of —28° F., in order to prevent the escape of too large a volume of gas during the process of its solidification. Attached to this valve, inside of the tank, is a tube which reaches within half an inch of the tank bottom, and is open at its lower end. We now attach to the valve a flannel bag to receive the solidified gas. Upon opening the valve the liquefied gas escapes, the solidified portion remaining in the bag while the gas formed escapes through the pores of the bag. This bag will hold about three-quarters of a pound of the solidified gas, and this is about the quantity which is now being emptied on the plate. A portion of this solidified gas will now be passed to you for inspection; another portion is packed into this wooden tube, a thermometer is inserted, and, as you will observe, the temperature falls to 118° below zero. Another portion is placed on one pound of mercury contained in this saucer; the intense cold of the solidified gas almost immediately solidi-

fies the liquid metal. A portion of the solidified gas, or "acetylene snow," is now dropped into this vessel containing water. Being lighter than water, it floats upon its surface, and when touched with a light the gas surrounding each particle of the solidified gas burns with a sooty flame, and continues to burn until all the solidified gas has disappeared. I will now ignite the gas evolving from the acetylene snow contained in this dish, and you have the interesting exhibit of a solidified gas at —118° F., giving off gas which can be ignited, and which, although evolved at this low temperature, possesses the same illuminating power as at higher temperatures. You have now seen acetylene in its three physical conditions, namely, as a gas, a liquid, and a solid; and the mere fact that it readily assumes the gaseous and liquid conditions is of vital importance to its commercial application."

Acetylene was first discovered and isolated by Davy, in 1837. He obtained it in the manufacture of potassium. In 1862, Woehler produced calcium carbide by heating a mixture of lime, zinc, and carbon to a white heat. He found that the carbide gave off acetylene gas when brought into connection with water, and his researches might have produced some results of commercial value but for his untimely death. In 1893, H. Moissan began experimenting with acetylene gas and calcium carbide. In 1894 he produced the carbide with an electric furnace operating with lime and carbon.

While attempting to procure metallic calcium by means of an electric furnace in 1894 or 1895, Thomas L. Willson obtained calcium carbide from a mixture of lime and carbon subjected to five thousand amperes. He has since built and patented an electrical furnace for the manufacture of this calcium carbide, in which he heats a mixture of

lime with some form of carbon, as coke or coal-tar, and obtains about one-third the weight of the original materials in carbide. By using limestone and coal-dust it is claimed that the calcium carbide can be made for fifteen dollars per ton, while the by-products obtained will still further reduce this cost. At the Willson Illuminating Company's plant, at Spray, North Carolina, about one ton a day is now being turned out from twelve thousand pounds of coal-dust and two thousand pounds of burnt lime, using one hundred and eighty horse-power. The quality is stated to be almost perfect, as five and three-quarters feet of acetylene gas are producible from a pound of the carbide out of a possible theoretical 5.89 feet. Negotiations are in progress between the Electro-Gas Company of New York City and the Niagara Falls Power Company, for the use of one thousand electrical horse-power to be used in making calcium carbide, with a privilege of extending the use to five thousand horse-power.

As a matter of fact, calcium carbide sells in the market at this time (May, 1895) for one hundred and sixty dollars a ton, so that those interested have a big undertaking on their hands to get it down to fifteen dollars. So sanguine are they, however, that one of the patentees claims that the cost will eventually be brought as low as five or six dollars a ton. Be that as it may, the eminent German firm of electricians, Siemens & Halske, have already lent their aid towards the establishment of a factory on the Continent for the manufacture of calcium carbide, to be used in making acetylene gas, showing that it is their judgment that this new illuminant is coming into use at once, and can be sold at a price that will cause it to be in demand.

Acetylene requires to be diluted with six hundred to one

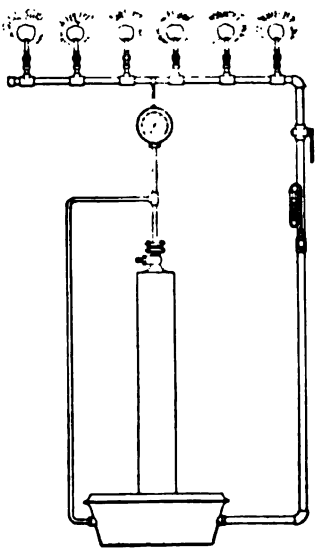
thousand per cent. of atmospheric air, to give forth the best flame. If burned in its natural condition without such admixture, it gives off a smoky flame. Acetylene is explosive if too much air be added, and considerable care must be taken in mixing them. Even expert chemists have met with accidents through allowing themselves to forget this. Some automatic system of regulating the mixture will have to be devised before the public is allowed to undertake its own mixing of the gases. The carbide can be kept a year or more without deterioration if the air is carefully excluded. Small quantities are conveniently stored in a tightly corked bottle, covered with kerosene or other petroleum oil. It then looks like a lustrous black mineral, but if exposed to the air it gradually disintegrates into a dull gray powder.

The ease with which acetylene gas can be liquefied, by applying a moderate pressure, makes it extremely probable that after a time it will be handled and sold in this form, as we now sell headlight and astral oil. In the liquefying apparatus the gas, upon escaping from the tank in which it has been generated, flows through a coil surrounded by water to condense and drain off as much aqueous vapor as possible. It next passes through another tank in which pieces of calcium carbide are exposed, in order to rob the gas of any remaining moisture. Then it is admitted through another coil, surrounded by a cooling mixture, and finally into the removable storage cylinder, which is connected with the apparatus.

Portable acetylene lamps are made with a stout steel gas-holder, about four by sixteen inches, fitted with a top opening of a size suitable to admit a stick of calcium carbide. There is an opening at the bottom of the gas-holder, which is normally closed, which may be used when desired

to clean out the lime left by decomposition. In operation water is poured into the lamp, and the burner screwed on. The stick of carbide, being coated with a slowly-soluble glaze, gives off gas as slowly as desired, the burner automatically absorbing such atmospheric air as is required for mixing. Such a lamp will burn ten hours without attention.

FIG. 71.



DOMESTIC ARRANGEMENT FOR BURNING LIQUID ACETYLENE.

An acetylene burner emitting half a foot an hour will give a light better than the average gas-jet, and the consumption of a foot an hour gives a light which is the equivalent of the incandescent electric light. Therefore ten pounds of liquefied acetylene gas will give a light the equivalent of the incandescent electric light for a period of one hundred and forty-five hours. For this service the

average electric-light company would charge one dollar and forty-five cents. It is likely that the acetylene gas eventually can be made for twenty-five cents per liquid ten pounds, and it would seem as though the public might expect to get it for not more than seventy-five cents or a dollar, until the patents expire, when we shall buy calcium carbide as we now buy coal, only at about double the price, and it will furnish us light, heat, and power at about one-fourth the present cost. Doubtless gas companies will soon take to furnishing it in the mains to consumers, though its easy liquefaction makes it so suitable for household use that it may eventually kill off the coal-gas industry altogether.

OIL-WELLS AND THEIR PRODUCTS.

Methods employed in obtaining Petroleum, and in refining and dividing Crude Oil into the Oils of Commerce.

PETROLEUM will always be an interesting fluid, the speculative element that attends its search giving it something of the same enchantment that leads men to dig for gold. The first Pennsylvania oil-well was sunk in 1859, since which time fields have been discovered in many parts of the world, and in several of the United States. Wyoming has several wells, and promises to be a large field. In Indiana the Terre Haute Gas Company, in drilling for natural gas, struck a good oil-field. Oil is also found near Toronto in Canada. When other nations take to boring the earth as generally as has been done in North America, no doubt the world's supply will be largely increased.

FIG. 72.

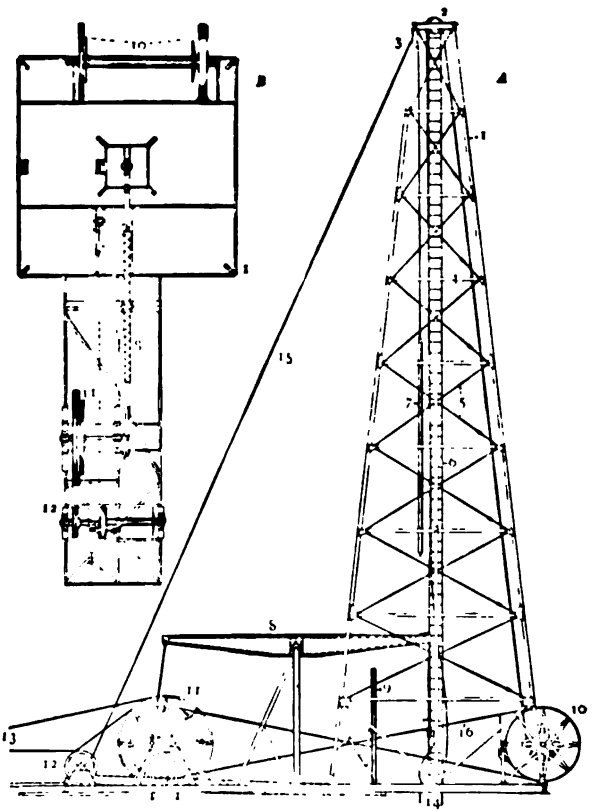


DIAGRAM OF A STEEL RIG FOR DRILLING OIL-WELLS.—*A*, Upright plan. *B*, Ground plan. 1. Derrick frame. 2. Crown pulley. 3. Sand-pump pulley. 4. Derrick girt. 5. Braces. 6 Ladder. 7. Bailer. 8. Walking-beam. 9. Headache post. 10. Bull-wheels. 11. Band-wheels. 12. Sand-reel. 13. Ropes connecting with steam-engine. 14. Top of well. 15. Sand-line. 16. Bull-rope.

A great deal has been written about oil-wells, gas-wells, and artesian wells in general, but somehow the average young person has a very indistinct notion of how they are drilled or operated. Many think the tools used in sinking

resemble big gimlets, that spiral their way into the marrows of Mother Earth. This error arises from a misconception of the words "bore" and "drill," which they hear used in this connection. They are not familiar with the rock drill, which is, strictly speaking, not a drill at all, but a cold chisel that can be made to cut a hole in the rock by means of repeated rapid blows. This is the sort of drilling that is meant when oil-wells are referred to, and which would be better understood if it were termed chiselling. Free-falling tools, suspended by a cable and worked by steam-power, are used, the weight of the tools being so great as to give blows of sufficient force to pierce the hardest rock.

The methods of drilling for petroleum are mainly what they were in the sixties, but the tools have been vastly improved since then, and the cost of sinking a well is much less. A good oil-well rig, with sufficient tools and piping to put down a two-thousand-foot well, costs only ten thousand dollars. Drilling is accomplished by raising and dropping a heavy tool on the rock. This is the same principle that was used in China a thousand years ago, the chief difference being that the Westerner uses steam and choice tools, while the Celestial was satisfied with a rope and man-power. Over sixty thousand wells have been sunk in the United States, most of them in Pennsylvania. An outfit consists primarily of a derrick, seventy to eighty feet high, made either of wood or steel, the latter being the best, as a matter of course.

Some of the parts bear odd names, as headache-post, bull-wheel, and sand-line. The headache-post probably received this name because of its trembling, the shaking giving a headache to any one obliged to stand near it. The sand-line is so named because it is used to operate the sand-pump. The bull-rope connects with the bull-wheels,

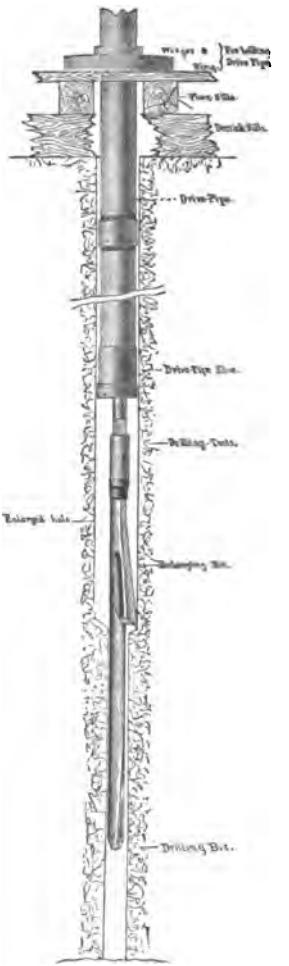
which are mounted on a shaft or reel carrying the principal cable used in rope-drilling.

The derrick has pulleys at the top, over which ropes are run to operate the tools. Drilling is begun by suspending a tool from the top of a derrick and jumping it up and down with a rope until a hole is made deep enough to admit a string of tools. These are then made fast to one end of a big walking-beam, that gives an up-and-down stroke of perhaps three feet. The string of tools is rather formidable, being usually about eighty feet long, and weighty in proportion. The top tool is the temper-screw, which is attached to that end of the walking-beam that is over the well, being designed to clutch a cable and lower it at intervals, and also to admit of constant rotation. The cable is slipped through the lower end of the temper-screw and fastened to a rope-socket, connecting with the sinker-bar, which is usually a heavy iron rod twenty feet in length, the weight serving to drive the drill.

There are sliding links called jars on the string of tools, preventing the blows from jarring the machinery and insuring the dropping of the whole weight of the string below the jars. It is the duty of a man at the top to keep turning this string of tools between blows, so that the tool's edge may cut in all directions. The upper part of the well, as sunk, is supplied with a pipe of eight inches inside diameter, called a drive-pipe, because it is driven in. A temporary head is screwed to the top of a length and the whole is sunk by pounding it down. Sometimes a big maul is used for this purpose, being raised and dropped by a rope from above, and sometimes a clamp is applied to the top of the string of tools, and they are alternately raised and dropped until the pipe is down far enough to resume drilling.

When the well has been continued in this manner perhaps for four hundred feet, a smaller size of pipe, called the casing, is inserted. This is usually of about five and a half inches diameter, and constitutes the major portion of the well. It is sunk into place with a disk of thin metal closing the lower end. The object of this is to allow the water that gathers in the well to assist in buoying up the great weight of the many hundred feet of casing. When work is resumed this disk is easily knocked out. Numerous packers are used to insure tightness between the pipes and between the pipe and rock. These packers are sometimes made of rubber and sometimes are simply inflated bags.

FIG. 78.



MANNER OF DRILLING OIL-WELL.

Inside the casing is placed the tubing, through which the working-barrel or pump is to be worked. This tubing is made anywhere from one to five inches in diameter. A temporary disk is also placed at the bottom of the tubing to keep out the oil until the workmen are ready for it to flow. The lowest section of tubing consists of a perforated pipe called the anchor.

When a tool becomes dulled in the operation of drilling it has to be removed and a sharp one inserted in its place. At such a time it is customary to pump out the sand in the hole. Special pumps are made for this purpose, having valves into which the sand is sucked and drawn out.

For cleaning the hole, bailers, sand-pumps, and swabs are used. A bailer is a tube with valves that may be let down, and fills with water. When it strikes the bottom the blow closes the valves, and it is hauled up full. The sand-pump is made on much the same principle. A swab is a pipe bearing a big rubber collar at the lower end. It is used to remove paraffine and the heavier oils from the well. There are valves that allow the oil to rise above the rubber collar, so that it may be drawn up.

The work of drilling is kept up night and day, and if everything progresses favorably it is most monotonous. But, as a rule, all does not run smoothly. No business under the sun (or under the ground) is more uncertain than drilling an oil-well. Tools and pipes have to be operated from a distance of hundreds and sometimes thousands of feet.

In drilling through earth down to the rock a broad, flat, dull tool is used. For drilling in the rock very heavy bits are required, so large that in handling them above-ground a truck has to be used.

Holes have a bad habit of working off to one side, as when a glancing rock throws the tool into softer material. This will not do, and when the workmen discover by the jamming of the tool that this is the case, they have to withdraw the string of tools, and substitute special tools designed to correct such faults.

Sometimes it is found necessary, in drilling through rock that has many crevices, to use a winged bit that will not

work off sideways and make the hole crooked. If the hole does become crooked a straightening-bit is required. This is a large bit, nearly the full size of the hole, with a protuberance on one side. Patent collars are also made to be screwed on to an auger-stem at various points, to keep the bit in line.

There is often serious trouble from the loss of tools that break or become disjointed. Any quantity of special tools have been invented to recover lost tools. Some are made with an inverted bowl in the lower end, having an internal thread or female screw to cut into the top of the lost tool, and obtain a grip upon it. Others take hold by friction, or with barbs. There are also grabs, and barbed spears to take up lost rope, and knives to cut off or chop up a rope. Sometimes a tool becomes so jammed that nothing can be done to withdraw it. A very long, heavy tool called a whipstock is then worked down to crowd the lost tools off to one side, and allow the well to go on.

When it is desired to remove the casing from a well for any cause a casing-spear is lowered into it. Properly speaking it is not a spear, but a device with an expanding screw, designed to obtain a firm hold on the inside of the casing. If the casing is so tight as to resist all efforts at raising, however, a splitter or cutter is put down, and the casing so cut as to allow the outside sediment to run into the well, when it is possible, usually, to remove the casing.

It is not uncommon for the drive-pipe to become indented by outside pressure, as from a loosened rock. This has to be overcome by dropping in a big swedge with a rounded end, and pounding it until the pipe is bulged back into shape. Sometimes difficulties arise which render it necessary to remove the casing. Perhaps it is full of sediment, and so loaded that its weight cannot be manipulated

from above. A casing-splitter is then run down to break it open and allow the sand and water to run out. If it is still too heavy after this, a circular cutter is inserted, and a length cut off that can be removed. Thus the searcher for oil is often obliged to destroy the work of weeks, and spoil expensive material, because of some stoppage or accident that would be trifling if his tools were within easy access above-ground.

FIG. 74.

A TORPEDO.

When at last the tubing is sunk into good oil sand, the workmen remove their drills, and lower a torpedo, charged with five to twenty pounds of nitro-glycerin. A piece of pointed steel called a go-devil is then dropped to set off the torpedo. The explosion is not felt seriously at the surface, but a great spout of oil comes surging up, and the well flows for a time until the pressure from below is relieved. The two-inch tubing before referred to is then sunk with a packer at the bottom, and the pressure thus caused sets the well to flowing again. When this pressure ceases to be effective pumping is resorted to again. This may continue for a year or more, until the well is exhausted, when another torpedo is used, and a fresh supply obtained. Few wells last over three or four years, after which time the owners should have acquired enough wealth to retire.

The deepest bored well in the world, so far as known, is in Silesia in Northern Austria. The depth was six

thousand five hundred and sixty-eight feet at last reports, and it is designed to extend it ultimately to eight thousand two hundred feet. The major portion of the boring is only two and three-quarter inches in diameter.

The refining of petroleum has been much improved under the fostering care of the oil trust. In the days of competition among refineries all discoveries of value were religiously guarded to prevent competitors from receiving the benefit of such improved methods. Now the superintendents confer together and exchange experiences, so that the processes in all American refineries are practically identical, and any useful improvement adopted by one speedily finds its way into all the refineries.

Crude oil is the name applied to petroleum in the condition in which it is obtained from the earth. To refine it a division of the oil into its various components is first requisite, and the products are then purified. From the lighter parts of the oil benzine is obtained. The heavy portions yield paraffine and wax. The residuum is tar, which when evaporated to dryness leaves coke.

The primary distilling is done in a cylindrical still of riveted sheet iron, set on its side with a heating apparatus underneath. A large blow-off valve in the top prevents the pressure from rising above one and a half pounds. The vapor that would thus be wasted is carried around below and used for fuel. The vapor proper is carried through a large pipe to a condenser, where it is cooled in a long coil of pipe of gradually-diminishing size, and then flows on to the monitor. This is a great kettle-like tank, having a double bottom with gates or sliding doors, through which the oil may be flowed to various other tanks. The first product of the condenser, light benzine, is here examined, and if all right switched to its proper tank, and so

on. Heavy benzine is then brought in from the condenser, then water-white distillate, etc., through all the grades, until the tar is reached, when the fires are allowed to go out, after which the tar is pumped from the still, and it is cleaned for a new run.

The products of this first distillation are muddy and foul-smelling. Some paraffine and some highly volatile oils remain in the benzine, and the latter would be dangerous to consumers. A further distillation in steam-stills is therefore necessary. This is accomplished after the manner of the first distillation, except that instead of igniting a fire beneath the still, steam is turned in to carry off the lighter impurities by vaporization.

From the steam-still's monitor commercial benzine is drawn. To purify the remainder the oil is pumped into an agitator, where the oil is forced through it by a blower. Sulphuric acid is introduced, which causes the impurities to settle after the agitation ceases. The impurities and acid are then drawn off from the bottom, and water is introduced, followed by further agitation with the blower. The oil is next drawn off into settling tanks, from which are drawn the various commercial products known as gasoline, naphtha, headlight, astral, water white, standard white, ship oil, etc.

The residue of the stills is subjected to yet another distillation to secure the remaining paraffine oil and its wax. Paraffine is drawn off in several grades, the heaviest being a stiff product suitable for wagon-grease or car-axles. The most solid part of the paraffine is chilled until it becomes like vaseline. It is then subjected to great pressure in a hydraulic press, and the solid product is a wax that goes to make paraffine candles, chewing gum, and many similar articles. The oil that flows from the paraffine press is

very light and fine, and is the so-called sewing-machine or bicycle oil of commerce.

The residue in the stills, after the paraffine is exhausted, is baked until dry, when it becomes coke, and is cooled and broken up.

Thus are the very numerous products of petroleum cheaply manufactured, nothing going to waste.

COAL-HANDLING MACHINERY.

The Massive Automatic Mechanisms devised for doing away with Manual Labor—Gravity and Cable Railways, Coal-Pockets, and Elevators.

THE methods employed in handling the enormous quantities of coal brought from the mines to large consumers have vastly improved within a few years. Formerly the coal which was dumped from the mine-tipple into a boat was emptied from the boat at its destination by a gang of sturdy coal-heavers, who, with much sweat of the brow, each handled an average of six tons a day. The hoisting of coal, with a rope and pulley, by horse power was the first improvement on hand power. Half-barrels were used as buckets, and the work of the shoveller was confined to filling the buckets. The poor horse was hard worked, and had to do a deal of backing, which he hated, but the system was a great improvement on using man power. The next advancement came about 1857, when George Focht devised an iron bucket so shaped that it was top-heavy when filled and bottom-heavy when empty, so that it was easily dumped and self-righting. By using a horse and this tub the coal could be removed at the rate of twelve

tons per man. The Dederick horse hoisting-machine was the next improvement. This was so rigged that the horse walked in a rotary path, and had no backing to do. Hoisting-engines came into use so soon after this that Dederick's machine was short-lived. These engines were used in connection with gravity railroads. The plan was to erect a tower on the wharf, hoist the coal, and tip it into a car which, when started, ran by gravity along an inclined railway to a coal-dump. There the force of the stoppage was used to tip the car, emptying it. The return was accomplished by means of a rope and weight, which the loaded car had raised on its down-grade journey, and which developed sufficient power to return the empty car to the point of starting. Thus the railway was automatic, but one man being required to start the car. This method is so good that it is still the means used where a moderate supply of coal is received. For large quantities more complicated mechanisms are preferred.

An automatic railway will handle as much as sixty tons of coal per hour. The early makes, with five men—three shovellers in the hold, an engineer, and a car-attendant—usually took care of about thirty tons a day per man.

The increased speed used in hoisting by steam made the swinging about of the heavy bucket a serious matter. This was overcome by the use of an elevator with inclined booms running out over the vessel, so that the hoisting was vertical until the level of the booms was reached, when the bucket proceeded up an inclined way to the place of tipping. With this apparatus larger buckets could be used, and the rate of unloading increased to forty tons per man daily. The increase in weight of the buckets, and the faster travel of the rope, caused rapid wear on the hoist-

ing-ropes. Wire ropes were tried as a substitute, but as the workmen in the hold found it very convenient to start loaded buckets up when ten or fifteen feet to one side of the hatchway, the sharp bend of the rope proved disastrous to the wire, breaking the strands. To obviate this, there has been introduced an all-manilla rope, laid up with plumbago and tallow. This rope proved slippery enough to stand the strains, and is the rope used to-day.

As the principal expense for manual labor was now in the shovelling of the coal, inventors next turned their attention to reducing the shovellers' labors. The accepted device is a steam-shovel, so called, but which in reality is a double-jawed grab, that descends, mouth open, upon the coal, closes its jaws, taking in from one to three tons, according to capacity, closing tight on the same, and starting on its upward voyage without any aid from the shoveller. That shown in Fig. 75 was built by the C. W. Hunt Company. This steam-shovel reduced the force in the hold to one man, whose duty was to clear out the corners, and assist the shovel in taking up the last remains of the coal near his hatch. With a one-ton shovel, the average speed of unloading cargoes of coal is from fifty to seventy tons an hour to each hatch, making a total of from five to seven hundred tons a day, or, three men being employed, from one hundred and sixty to two hundred and thirty tons per day for each man—a gain of about thirty-five to one in forty years.

The cost of unloading a coaler is still further reduced by the use of vessels whose holds are so shaped that the coal naturally slides by gravity within reach of the shovels. The cost of unloading large vessels varies between one and a half and three cents a ton.

Equally improved means have been adopted for storing

and conveying coal after unloading. The universal custom used to be to dump the coal on the ground in great heaps, and leave it in the weather. Then manufacturers and dealers who used large quantities found that it paid to

FIG. 75.

A STEAM COAL-SHOVEL AT WORK.

build sheds, which, in course of time, came to be very large, and the teamsters wasted as much time in getting the coal out as it cost under old methods to get it in. To obviate this trouble, the coal-pocket was invented. It is a storage building, made very strong, and set up on posts one

story above the ground, so that teamsters can drive underneath, and load their carts by simply drawing the door of a chute in the floor of the building above them. Advantage is taken of this handling to screen anthracite coal by sliding it across a sieve in loading. Thus it goes clean to the user.

When it is desired to convey the coal more than six hundred feet from the wharf, the automatic or gravity railroad ceases to be serviceable, and cable-roads are constructed. These roads are also largely automatic. They make use of an endless cable, and a number of small cars. When a car is loaded, a workman steps aboard, grips it to the cable, and steps off. The car proceeds entirely unattended, at a speed of about three miles an hour, dumps its load automatically at the terminus, or wherever the tripping device has been set, turns around a half circle, and returns to the point of starting, where the workman again steps on, unloosens the grip, and puts the car in place for reloading. These cable-roads are run over any sort of ground, up-hill and down, around curves, etc., without serious difficulty. There is one at West Point that carries coal and supplies from the wharfs on the Hudson to the level of the bluff three-quarters of a mile away, at an elevation of one hundred and thirty feet, over a tortuous path. The expense of running the road is very slight, as the cars require no attendance.

Another method of handling coal is by conveyors. These are made in several forms. The Hunt conveyor consists of a row of iron buckets hung between endless parallel chains. These buckets are run along very slowly, and may be filled from a continuous filler or by any convenient method suited to the plant. They are dumped by tripping devices set at the desired point, and the line

of empty buckets returns underneath the line of filled buckets.

The Dodge trough chain-conveyor utilizes a sheet-iron trough, along which, at intervals of a few feet, are dragged sheet-iron scoops, that draw the coal along to the place of deposit.

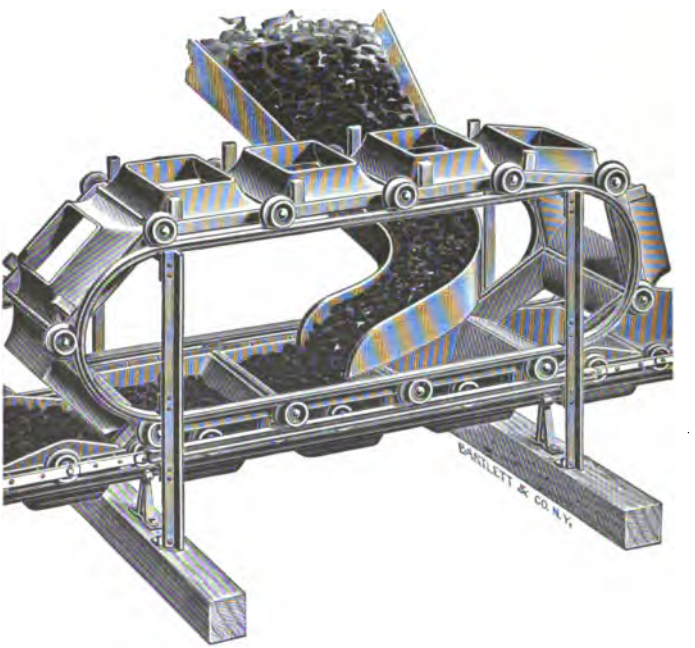
In handling coal which has to be stored on the wharf for a time the usual method is to employ several travelling elevators, running on a track, on the edge of the wharf, where their booms can be swung out over the vessels. If there are cars ready to be loaded, the coal is dumped directly into them, on the opposite side of, or directly underneath, the elevator. But if there are no cars, and the coal is to be stored, it is dumped into a conveyor that carries it up an incline, dropping it so as to form a great conical heap on the wharf. There is a separate pile for each size and kind of coal, and when it is desired to gather the coal from the piles to load into cars, a conveyor running on the level of the ground, and working up against the heap radially, will remove the whole at a rapid rate, leaving the ground almost clean of coal, without the aid of hand labor.

Several forms of fillers are used for conveyors, of which the spout continuous filler is perhaps the most ingenious. Its operation should be easily understood from Fig. 76. The conveyor-buckets move slowly and continuously on the long chain, while a series of guides revolve on a short endless chain. The coal coming in from the spout cannot spill between the conveyor buckets, owing to the guides, and the arrangement insures each bucket being loaded in a level and even manner.

The elevated railroads have a specially-devised method of storing coal for the convenient loading of locomotives.

A large coal-pocket is erected near the tracks. From this run endless conveyors to a smaller coal-pocket built above the tracks. The conveyor-buckets pass under the large coal-pocket and receive a supply of coal from one or more chutes. Then they pass to the top of the small coal-pocket, where they dump their loads. The locomotives

FIG. 76.



THE C. W. HUNT COMPANY'S CONTINUOUS FILLER.

can stop under the small coal-pocket and take in a tender-load of coal through a chute without delaying a train any longer than the ordinary stoppage at a station.

In electric-light stations, gas-works, etc., it is usually desired to get rid of the ashes as well as bring in the coal.

For this purpose the endless conveyors, after bringing in coal and depositing it at the boilers, are led to the under side of the ash-pit, from which they receive the ashes by means of a filler, and carry them to a place of deposit, usually an elevated pocket outside of the buildings, where they are left while the conveyors continue their round. For outside conveyors the C. W. Hunt Company manufacture a patent non-freezing engine, so constructed as to be without pockets in which water can lodge and freeze.

FIG. 77.

THE HUNT ELEVATORS UNLOADING A SHIP.

Ocean steamers use the conveyors to bring the coal from the bunkers to the boilers, doing away with coal-passers. Steamers are also loaded with coal by means of the conveyors, which are run direct from dump-cars over the freeboard of the vessel and down the hatch. The coal gets a fall of two or three feet in dumping, which does not break it materially. Another mode of loading steamers is by means of floating elevators, which are run between the steamer and the coal-barge from which the coal is taken, and hoist the coal directly into the steamer.

In addition to the machinery described, a great variety of more or less ingenious dump-cars are manufactured, and a recent car has been brought into use for depositing its load all in one small spot, as the mouth of a chute, without tipping the car. This is accomplished by building the car very high for its width and length, and placing the discharge gate at one corner, which is sufficiently lower than the other corners to cause all the coal to slide that way by gravity.

Where there are two thousand five hundred tons or less of coal handled annually by a manufacturing concern the automatic or gravity railway answers all purposes, provided the distance is not great. Up to five thousand tons a year an improved hoisting-engine and self-dumping buckets of half a ton capacity should be used, together with a substantial coal-pocket. If over five thousand tons a year are received, it pays to put in a steam-shovel, and for ten thousand tons or more the very best outfit obtainable is the cheapest. Where the cargoes are large, and the vessels in a hurry, as is apt to be the case at the ports on the Great Lakes, where steamers tow up a line of barges at a time, it is desirable to use several elevators with the largest size steam-shovels, working all the hatches at one time. The Lehigh Coal and Iron Company, at West Superior, Wisconsin, have nine elevators at one plant, capable of working in almost any combination, as from three hatches in each of three vessels, or from five hatches in one vessel and four in another. This is all done to save time, as vessel owners prefer to do business with those who detain them least.

These elevators are built with interchangeable parts in different standard sizes, according to the work expected of them. The smaller size is suitable for handling buckets

of less than one ton capacity. The medium size is for the regulation steam-shovel that makes so much speed. A special size is built for handling ten-ton boxes of coal, a form sometimes used in shipping from cars to vessels. In all the styles horizontal booms are used that swing laterally so as to cover at least two hatches of a vessel without moving the elevator. The chock on a set of booms is movable, so that the bucket can be made to descend at any point from the extreme outer end of the booms to the inner side of the vessel. In operation, the engine hoists the bucket vertically from the hold of the vessel until the running-block attached to the tub strikes the truck on the projecting booms. As the engine continues to hoist the tub and truck, both run up the boom until over the hopper or car, when the bucket strikes a dumping attachment, which deposits the coal. The rope is then slackened, permitting the truck and the bucket to run down the booms until the truck strikes the chock, which arrests the motion of the truck. As the engine continues to pay out the rope, the bucket then descends vertically into the hold of the vessel, when the steam-shovel fills itself with coal. In hoisting with a steam-shovel, but one is used to an elevator; but if tubs are used, three to five of them may be operated at once, as they are not run with the speed of the shovel.

When docks have a long water-front, the elevators are set on double-flange wheels running on a track parallel with the water-front, or on top of the trestle-work or the building. The engine is placed inside the elevator, and the whole affair can be moved to any part of the wharf-front. In this way the whole front is available for hoisting, and only as many elevators are bought as may be required at one time.

Very recently a plan has been suggested for pulverizing

all the coal at the mines and sending it through pipe-lines by a flood of water. Coal is very little heavier than water, and can be carried along readily. On receipt it is proposed to subject the powdered coal to hydraulic pressure, moulding it into lumps of any desired size. If this shall prove feasible the methods of coal-handling may be changed entirely, and the railway monopolies that now control the output of coal may give way to a pipe-line monopoly that will strive to emulate the Standard Oil Company.

ICE-MAKING AND REFRIGERATING.

The Theory and Practice of manufacturing Artificial Cold—Value of Natural Gas in this Connection.

THE manufacture of ice and the production of machines for causing artificial cold have increased to large proportions during the last generation, and numerous and varied mechanisms have been invented for assisting the commercial progress of the industry. In order that the reader may understand how these machines operate, a slight knowledge of the physical laws on which they are based is requisite. It should be understood that permanent gases, such as hydrogen, or compound gases, as the air, are only forms of matter, which, if subjected to sufficient pressure and cold, become condensed and liquid. Steam condenses into water when below a temperature of 212° F., while ammonia boils at — 28½°. By subjecting ammonia to pressure its boiling point is raised in proportion to the pressure. It follows that by taking ammonia gas and subjecting it to pressure, thus enormously increasing its heat, and then

pouring cold water on the vessel containing the compressed ammonia, we shall liquefy it, and if we later allow the liquefied ammonia to expand by removing the pressure, it falls very rapidly in temperature, losing theoretically as much heat as we added to it by compressing. On this principle a large number of convenient gases may be used to produce artificial cold.

Saline solutions and endothermic combinations are the features which have been employed by some in the manufacture of similar machines, but such have not been markedly successful.

Another method has been the vaporizing of a more or less volatile liquid in a vacuum, and afterwards allowing the escape of the vapor into the atmosphere, or absorbing it in some manner. This is called the absorption system, and was introduced by a Frenchman named Carre, whose ingenuity brought him considerable celebrity, but his system proved both dangerous and complicated, and was finally abandoned by him. He used water as the volatile liquid, and sulphuric acid as the absorbent. His method was improved by Blythe & Southby, by substitution of condensation for absorbtion of the vapors, but the product was so small that it did not pay expenses. The Reece, Stanley, Pontifex & Wood, and Kropff machines are all of this order, and open to the defects of the system, which has failed of general adoption, though because of the cheaper price this class of machines has had some sale.

The process generally recognized as practical, and most widely employed, is that of the expansion of a compressed gas, or of a liquefied vapor cooled during its compression. Two classes of machines come under this head, those which employ compressed, and those which use liquefied, gases. Those that liquefy the gas are called compression-machines

when the liquefaction is accomplished by compression, and if a solution is used they are termed affinity-machines. Air frigoric machines are much used for cooling the holds of vessels for the preservation of fruits and meats and similar uses where a great degree of cold is not demanded or where the amount of production is a secondary consideration.

Machines utilizing gases liquefied by compression are the most common in use, which is equivalent to saying that they are the best for general purposes. In these the gas is liquefied during compression and vaporized during expansion. They have the advantages over air machines that they occupy less space and yield a larger product. Among the gases which are used or may be used in them are ether in various forms, ethylene, carbonic acid, chloride of methyl, and ammonia. The ether machines, despite the advantages of low pressure, have gone out of use as dangerous. They furnished about fifteen pounds of ice to a pound of coal.

Chloride of methyl is used in the Crespio machines. The Pictet, Reece, and Mackay machines make use of sulphuric acid, which liquefies at a low pressure, and is inflammable. They are particularly adapted for use in countries where the temperature is high all the year round. Carbonic acid frigoric machines are used to some extent, the compressing mechanism required being very small, about one-fifteenth the size of ammonia-compressors. As they are run under much higher pressure, this advantage is somewhat nullified.

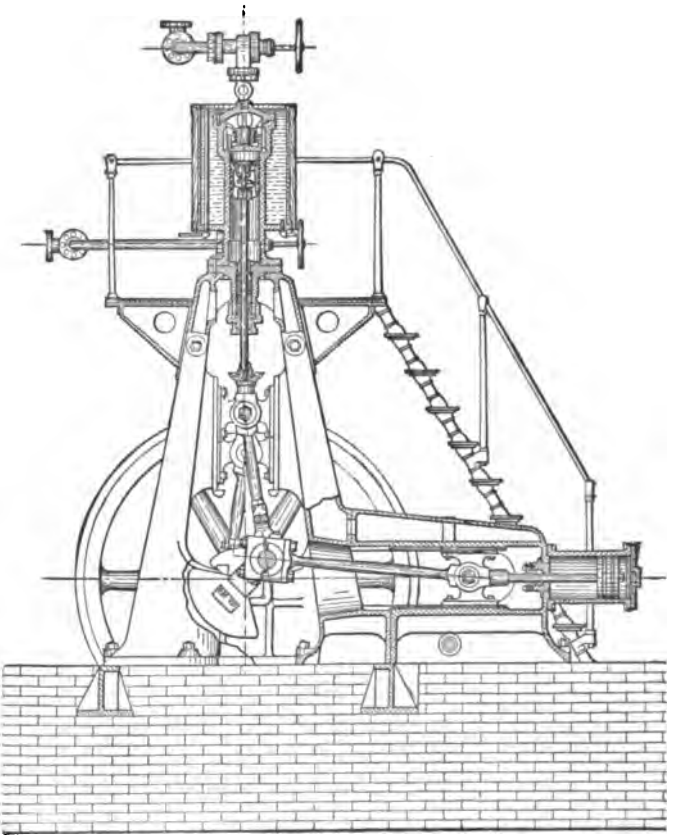
The gaseous ammonia frigoric machines command the largest market, though the mechanism is not the cheapest. They employ anhydrous ammonia, that is ammonia free from water, and this is obtained by distillation of the com-

mon form of ammonia. They can be relied on to produce about thirty-two pounds of ice per pound of coal consumed. Before describing these in detail it may be well to understand just what ammonia is. Chemically it contains three parts of hydrogen and one of nitrogen. It is obtained principally from the ammoniacal liquid manufactured as a by-product in the making of coal-gas, and from the liquid manure of stables. It boils or becomes gaseous at 28½° below zero.

In its simplest form an ammonia frigoric machine consists of three parts—an evaporator or congealer, in which the ammonia is vaporized; a suction or compressor pump for sucking in or aspirating the gas formed in the evaporator as fast as formed; a liquefier or condenser, into which the gas is forced by the pump, and by the pressure of the pump, combined with the cold maintained in the condenser by flowing water, reconverted into a liquid, to be again used in the congealer. The compressor-pump and condenser are required only because ammonia is expensive and must be used over and over. To utilize the cold produced by this form of apparatus either of two methods is employed—the brine system or the direct-expansion system. In the brine system the congealer contains numerous ammonia-evaporating coils, that are surrounded by a strong brine made with common salt, which does not freeze readily. The evaporation or expansion of the ammonia in these coils robs the brine of heat, the process of thus storing cold in the brine going on continuously, and being regulatable by a gas-expansion valve. This brine may then be circulated by means of a pump throughout the rooms or apartments which it is desired to cool, much after the manner in which we circulate heat in steam-pipes. In the direct-expansion system there is no brine used, but the

expansion- or evaporating-coils are placed directly in the rooms which it is desired to cool, so that the air is reduced in temperature.

FIG. 78.



SECTIONAL VIEW OF THE FRICK COMPANY'S ICE-MAKING MACHINE.

The brine system is considered preferable to the direct-expansion system for several reasons. It requires the use of less ammonia, a saving in first cost. The danger of

leakage of the ammonia is much less, since it is all contained in one room, or two at most, and not distributed all over the premises. Leaking ammonia is deleterious to goods as well as to human beings. The pumping machinery can be stopped at night, with very little increase of temperature, whereas in the direct-expansion system the frost on the pipes is depended upon to maintain the cold at night, and tends to melt and fill the rooms with moisture that is apt to be damaging to goods.

The machines used for refrigerating by the above-described process are a compressor-pump and steam-engine combined, the one shown in the illustration being the Eclipse type, made by the Frick Company, of Waynesborough, Pennsylvania. The larger sizes are about eighteen feet high, and have an ice-making capacity of one hundred and fifty tons every twenty-four hours.

The manufacture of ice in the United States is largely confined to the Southern States, for the obvious reason that in the North it is cheaper to gather it and store it in ice-houses. Machine-made ice has the advantage of being much purer than river-ice, since the water used is easily filtered, distilled, or otherwise rendered pure before freezing. Manufacturers exhibit photographs of cakes a foot or more in thickness to show how glass-like and transparent it is, objects in the rear being distinguished with great ease. It is claimed that artificial ice requires more time to melt than natural ice, because of its density, absence of air, and low temperature. Anyway, it is a fact that the ice-machines are every year creeping farther North, and manufacturers of ice-machines claim that they will some day drive out the natural article.

An ice-making plant is expensive, and consists of an ice-machine, with a pair of single-acting gas compressor

pumps, and steam-engine, with separators, gauges, and connections; an ammonia-condenser, with liquefying coils, etc.; system of tanks, ice-moulds, evaporating coils, wood grating and covers, cranes, thawing apparatus, agitating apparatus, distributing pipes, shafting, etc.; distilling and purifying system, consisting of a separator, purifier, distiller, and various tanks and filters; steam-boiler plant, with pumps, etc.; water-pumping system, with pumps and pipes. If a cold storage-room system is desired in addition, then a brine-tank and pump, with a system of pipes, are also required.

Ice is made in two forms, by the can system or the plate system, the names indicating the form of the ice produced. Can moulds are made to hold from one hundred to three hundred pounds, or slightly more to allow for waste before reaching the consumer. These cans are filled with distilled water from a tank and stood in a row between ammonia-pipes in a tank of cold brine. When properly congealed, the ice in the cans is carried out by overhead travelling cranes. In making ice by the plate system a water-power is desirable, as no steam- or distilling-apparatus is required to make transparent ice, and a steam-engine and boiler are therefore non-essential. Cakes are made eight by sixteen feet in size and twelve to sixteen inches thick. From eight to twelve days are required to freeze one of these great cakes, and they are handled by cranes as readily as the can-ice. As the plate system is the latest thing in the business, a description of its operation is in order.

The tanks being cleansed and everything in good working shape, the ice-compartments are filled within about nine inches of the top with water drawn through filters. The freezing-cells are filled with brine, the liquid ammonia expansion valves are opened, and carefully watched and

adjusted. A much larger feed is required at the start, as the water, brine, tanks, etc., are all comparatively warm, and will evaporate a larger quantity of ammonia in the coils than after the water has been cooled to the freezing-point and the formation of ice begins. The coils then require a reduced feed to prevent heavy frosting on the suction side. To ascertain when the ice is of proper thickness, there are oblong holes left in the compartment covers, through which a gauge can be inserted to test the ice. When the ice-cakes in a compartment have formed on either side and extended within about four inches of each other, it is time to shut off the ammonia valves, as the ice-building will continue for ten or twelve hours longer because of the stored cold, and will add perhaps another inch to the thickness of the cakes. The brine is then drawn off from the tanks, also any turbid water remaining in the freezing compartment. The brine-coils are then filled with water from a thawing-hydrant, at a temperature of 50° to 60°. This is done to loosen the cakes from the compartments, to which they are frozen fast. Chains are then passed around the great cakes and they are hoisted out. The ice-plate is taken at once to the cutting-table and sawed up into commercial sizes. This system is used by the Consumers' Ice Company of New Orleans, which is believed to have the largest ice-factory in the world.

Within a year or two it has occurred to some American engineers that a natural-gas well afforded the most convenient and cheapest means of manufacturing ice to be found anywhere. Probably this idea was late in developing because the gas-wells are mostly found where natural ice is plenty and cheap. However that may be, a company was formed in Indianapolis in 1894 for making ice and establishing cold-storage facilities in connection with nat-

ural gas. It must be remembered that natural gas issues from the wells at a pressure sometimes as great as twenty atmospheres, and at the uniform temperature of 42°. According to Pictet's formula, by expanding a gas from a pressure of twenty atmospheres to that of one atmosphere, its temperature would be reduced 318° Fahr. From this it is figured that a thousand cubic feet of gas, allowed to expand in coils in freezing tanks, ought to produce a result of seventy-two pounds of good ice, if we assume that the initial temperature of the water is 62°. An average gas-well may be said to supply a million and a half cubic feet per day, which would give a theoretical product of fifty tons of ice per diem—or, say, a practical result of thirty tons a day, at a cost of about eighty cents a ton. This would detract nothing from the value of the gas for heating and lighting, and would be a clear profit. It is quite within reason to presume that within a few years the gas-wells of Indiana and Ohio will supply those States and outlying territory with all the ice they can use, just as they now furnish nearly all the required heat and a large share of the light.

ALUMINUM, THE METAL OF THE FUTURE.

The Process by which it is now obtained, its many Valuable Qualities, and the Numerous Uses to which it is being applied.

THAT aluminum is destined to supersede steel, iron, copper, or any other one of the useful metals, no one who has given attention to the subject will for a moment contend. It has, however, a great variety of valuable uses, and fills a long-felt want. Its value lies in its freedom

from corrosion, its light weight, and its handsome appearance. It has long been known to exist, but only within a few years has it been possible to produce it at a moderate cost, electric decomposition being made use of to secure the metal. It is now manufactured on a large scale by the Pittsburg Reduction Works at Pittsburg, and will shortly be made on a larger scale at their new works at Niagara Falls. It is also made at Spray, North Carolina, by the Willson Aluminum Company, and at Lamont, Illinois, by the Illinois Pure Aluminum Company. In this country the Hall process is principally used, and in Europe the Herault-Kiliani and Minet processes.

The Hall process, which takes its name from Charles M. Hall, of Oberlin, Ohio, the inventor, is thus described by him:

"I form an electrolyte, or bath, of the fluorides of calcium, sodium, and aluminum, the fluorides of calcium and sodium being obtained in the form of fluor-spar and cryolite, respectively, and the fluoride of aluminum being obtained by saturating hydrated alumina (Al_2HO_6) with hydrofluoric acid. The compound resulting from the mixture of the above-mentioned fluorides, which is represented approximately by the formula $Na_2Al_2F_8 + CaAl_2F_8$, is placed in a suitable vessel, preferably formed of metal and lined with pure carbon, for the purpose of preventing the admixture of any foreign material with the bath or with the aluminum when reduced. The vessel is placed in a furnace, and subjected to sufficient heat to fuse the materials placed therein. Two electrodes of any suitable material, preferably carbon when pure aluminum is desired, and connected to the positive and negative poles of any suitable generator of electricity, preferably a dynamo-electric machine, are placed in the fused bath, or, if desired,

the carbon-lined vessel may be employed as the negative electrode. Alumina in the form of bauxite, anhydrous oxide of aluminum, or any other suitable form of alumina, preferably the pure anhydrous oxide Al_2O_3 artificially prepared, is then placed in the bath, and, being dissolved thereby, aluminum is reduced by the action of an electric current at the negative electrode, and, being fused by the heat of the bath, sinks down to the bottom of the vessel, the bath being of a less specific gravity than the aluminum. This difference in specific gravity is an important feature of my process, as the superincumbent bath serves to protect the aluminum from oxidation. The oxygen of the alumina is liberated by the action of the electric current at the positive electrode, and, when the latter is formed of carbon combines therewith and escapes in the form of carbonic oxide (CO) or carbonic acid (CO_2).

"As the aluminum is reduced, more alumina is added, so that the bath may be maintained in a saturated condition with the fused alumina. The addition of more alumina than can be dissolved at one time is not detrimental, provided the bath is not chilled, as such excess will sink to the bottom and be taken up by the bath, as required.

"The proportions of the materials employed in forming the bath or the electrolyte are approximately as follows: Fluoride of calcium, two hundred and thirty-four parts; cryolite, the double fluoride ($Na_6Al_2F_{12}$), four hundred and twenty-one parts; and fluoride of aluminum, eight hundred and forty-five parts by weight. These proportions, however, can be widely varied without materially changing the efficiency of the bath. During the reduction of the aluminum the positive electrode, when formed of carbon, is slowly consumed and must be renewed from time to time, but the bath or electrolyte remains unchanged for a

long time. In time, however, a partial clogging occurs, which, however, does not render the bath wholly ineffective, but does necessitate an increase in the electromotive force of the reducing current, the resistance of the bath being increased in proportion to the degree to which the bath becomes clogged, thereby increasing the cost of reduction. In order to entirely prevent any clogging of the bath, I add approximately three or four per cent. (more or less) of calcium chloride to the bath or electrolyte hereinbefore described. As the addition of the calcium chloride prevents, as stated, any clogging or increase of resistance in the bath, it can be used continuously without renewals or any additions, except such as may be needed to replace loss by evaporation, and without increasing the electromotive force of the reducing current, and, further, the addition of the calcium chloride enables each atom of carbon of the positive electrode to take up two atoms of oxygen, forming carbonic acid (CO_2), thereby reducing the amount of carbon consumed in proportion to the amount of aluminum produced. The calcium chloride being quite volatile is subject to loss faster than the rest of the bath, and must be renewed occasionally on this account.

"In reducing aluminum, as above described, I prefer to employ an electric current of about six volts electromotive force, but the electromotive force can be varied within large limits."

Aluminum, the metal, thus obtained from alumina, the earth, which is very common, has the following properties:

1. Extreme lightness. A cubic foot weighs one hundred and sixty-eight pounds, while the same quantity of cast iron weighs four hundred and forty-four pounds; bronze, five hundred and twenty-five pounds; wrought iron, four hun-

dred and eighty pounds; and structural steel, four hundred and ninety pounds.

2. High resistance to corrosion. Almost all of the common metals rust when exposed to a moist atmosphere, but aluminum is scarcely affected after prolonged exposure.

3. Tensile strength, ranking next to steel and iron if the comparison be made by weight and not by bulk. Its torsional strength is about the same as that of copper.

4. Conductivity, rendering it useful for electrical purposes. Here it stands next to copper and gold, silver being the highest. It has more than three times the conductivity of iron, hence is very suitable for telegraph and telephone wires.

5. Malleability. It is extremely ductile, and can be hammered, rolled, stamped, or pressed with ease.

6. The numerous valuable alloys into which it enters.

The property of lightness has had much to do with the introduction of aluminum for domestic utensils, and has also caused it to be in demand in the construction of certain parts of machines where momentum was to be overcome. Many have had the impression that it was the best material for bicycle construction. This is not so, since, weight for weight, steel is the stronger. It has been alloyed with steel, however, in making bicycle frames, with good results. For boat-building it is much favored, being only three times heavier than most woods, and resisting the corroding action of the water. Yarrow & Co., the famous English firm of boat-builders, constructed a small torpedo-boat with a hull of aluminum, in 1894, with which they were well pleased. A steel framework was used. Aluminum racing shells have been built of about fifty pounds' weight, which were considered better than cedar. The record on the Schuylkill River course has been

lowered nine seconds by their use. For constructions under water this metal has been successfully used, and is undoubtedly the best for such purposes. Care must be taken to use pure aluminum, however, as the alloys are sometimes lacking in this quality. The corrosion in sea-water is a little more than one-thousandth of an inch per year, an amount not worth figuring on. This non-corrosive quality renders it further useful in connection with steam. Being more porous than iron or steel, it has to be made thicker when cast for use in steam apparatus.

Aluminum is dissolvable by several acids, as hydrochloric acid, or concentrated sulphuric acid when the aluminum is heated. A strong solution of caustic alkali also dissolves it, and ammonia has a partially dissolvent action upon it.

Aluminum has been rolled as thin as the one two-thousandth of an inch, and in the form of leaf-metal is especially suitable for decorative purposes, its rich, silver-white color being easily maintained. Those who visited the Transportation building at the Columbian Exposition will remember the artistic leaf decorations of this metal that attracted so much attention.

The casting of aluminum is accomplished with comparative readiness. It melts at about 1160° F., and should not be heated much hotter, or it will occlude (that is, absorb) the air to some extent. The shrinkage is double that of iron, being a minute fraction over a quarter of an inch to the foot.

Aluminum is used as an alloy for steel castings, largely because in this case it tends to prevent the retention of the gases otherwise occluded in the steel, and thus tends to insure sound castings, which, until recent years, were not universally obtained. The alloying of aluminum with cast iron tends to convert the combined carbon in the iron

into the graphitic state, softening the iron, reducing the shrinkage, and lessening the tendency to chill. A slight quantity of it much improves an inferior grade of pig iron.

Aluminum-bronze alloys are among the most valuable discovered up to date. The proportion of aluminum used varies from five to eleven and one-half per cent. It is stated that the ten per cent. bronze has been made in forged bars with a tensile strength of one hundred thousand pounds to the square inch, the elastic limit being sixty thousand pounds, and the elongation ten per cent. in eight inches. This alloy is yellow in color, and melts at about 1700° F. It is malleable at a red heat, a peculiarity which is quite convenient, as none of the other bronzes are malleable at a high heat. As an acid-resisting combination aluminum-bronze stands high, and it is being used for coal-screens and similar articles subject to acid mine waters, and in parts of machines used in the manufacture of acids.

The addition of about one-half of one per cent. of aluminum to Babbitt metal has proved sufficiently valuable to become the subject of a patent by A. W. Cadman, of Pittsburg. It assists the malleability of Babbitt metal so that it can be more readily rolled into bar-form.

Lead and mercury are the only metals with which aluminum will not alloy, though combination with antimony is accomplished only with difficulty. A little silver added to aluminum improves its color and adds strength. This combination is well suited to various surgical and scientific instruments.

An alloy of about thirteen parts tin with aluminum gives a combination that has the merit of casting with very slight shrinkage, and might be useful as a substitute for electrotype metal. Both zinc and brass are improved by slightly alloying with aluminum, the galvanizing

properties of the latter being increased. Cast aluminum is much improved by the addition of about fifteen per cent. of zinc and a minute quantity of tin.

It is in being soldered that aluminum falls short of one's expectations. About twenty different combinations of metals are prescribed as useful in soldering aluminum or its alloys, which may be taken as a sign that none of them are good for much, else the best would have been sifted out for use. The trouble is that aluminum, being an excellent conductor of heat, draws the heat out of the soldering compounds before they can flow sufficiently.

For domestic utensils aluminum is destined to be in increasing demand. They are so pretty, so light, and so easy to keep clean, and they cost just enough more than other kinds to make them fashionable. The Illinois Pure Aluminum Company manufactures a complete kitchen outfit, from coffee-pot to frying-pan. It is certain that water can be boiled quicker in an aluminum pot or pan than in a vessel of any other metal—for two reasons, the aluminum is made very thin and it is an excellent conductor of heat. For covered dishes designed to retain the heat aluminum is the best metal we have.

The cook-rooms of the government cruisers "San Francisco" and "Montgomery" are each supplied with sixty-gallon steam-jacketed kettles. Hotels and eating-houses will not be long in adopting these utensils of aluminum, as their extreme durability renders them cheap in the long run. It is a remarkable feature of some of these utensils that they are cast, and not stamped. A tea-kettle can be cast only the sixteenth of an inch in thickness that will stand an amount of banging and denting which would lead any one not familiar with the facts to suppose that it was made of rolled or stamped metal.

Among the odd uses to which aluminum is put may be named: slate-pencils, which are simply bits of aluminum wire, that mark a slate as well as if made of the slate itself, and which do not break or wear out; horseshoes, which are said to last better than iron, and of course the lightness is a point in their favor; sounding-boards for musical instruments, giving forth a sound of a character different from that called metallic, and more musical than the wooden sounding-boards in common use; printers' type, giving a metal that is indestructible as compared with the soft alloys in use, and which is equally free from rust, and that casts readily.

From the above it will be seen that aluminum has so many varied valuable qualities that its use is sure to extend. Unfortunately, there is no present prospect of a reduction in the cost of obtaining it. The metal exists in great plenty. When some cheaper means of releasing it from the earth are found it will be in still greater demand.

WIRE NETTING IN GLASS.

A Recent Product of American Inventive Genius that is coming rapidly into Use—Description of Various Processes.

IRE-GLASS is the shortened name given to the combination of wire netting and glass that has come into use within a few years. When the necessities of the travelling public obliged railway corporations to build great stations, with wide-arched roofs spanning perhaps a dozen tracks, it was found that the only practical way of lighting such buildings was to make

the roof largely of glass. As glass panes in a roof have a bad habit of occasionally breaking and dropping dangerous fragments, it became necessary to protect the people below from accident, and the companies from suits for damages, by placing nettings of wire below the glass, thus supporting broken fragments until such time as it might be convenient to make repairs. This answered tolerably well for a time, but the netting was found to be very perishable when exposed to the corroding influence of the gases and smoke that invariably rise in a railway station, chemical works, etc., while in other large buildings where it was so used its life was short, and it became almost as much of a nuisance to keep it in repair as to take care of the broken glass.

In September, 1892, Frank Shuman patented a process of making wire glass which has changed all this, and the transparent roofs of a large building can now be made as permanent as the rest of the structure. Mr. Shuman was not the first to think of embedding the wire in the glass, but he was the first to concoct a method of embedding it that was commercially practical. When so embedded the glass protects the wire from corrosion and the wire adds strength to the glass, and it is very seldom that a broken fragment will not be sustained in its place, so that the whole combination is extremely satisfactory; and, although Mr. Shuman's invention was not fairly on the market until late in 1893, there are now (1895) two large concerns in the United States engaged in its manufacture—the American Wire Glass Manufacturing Company, at Tacony, Philadelphia, and the Mississippi Glass Company, at St. Louis, Missouri. The works of the first-mentioned company cover an acre and a half of ground, and they keep an eight-pot Siemens's regenerative furnace of the latest design busy melting ten tons of glass per diem.

The first invention of which there is record relating to the combination of wire and glass was made by one Newton, who secured a British patent in 1855. He had a notion that wiring was desirable for the purpose of making glass fire-proof and burglar-proof. He proposed to pour a thickness of glass in a mould, lay on a sheet of wire netting and then pour on more glass, after which the whole was to be subjected to pressure. Whether he ever really tried the process is not known, but if he did subsequent experience goes to show that he met with disappointment, as wire cannot be satisfactorily embedded in this manner, because it heats and warps. In 1871, Thaddeus Hyatt, of England, appeared on the scene with another and better process, and experimented largely. His plan was to stretch the wire netting in a mould, then to pour the molten glass on top of the wire, and force it through by hydraulic pressure. He found it impossible to keep the wire netting in the centre of his glass sheet. It would sag and warp. The glass could only be made in very small sizes at a cost beyond what it might be expected to bring when sold. He was therefore obliged to abandon the enterprise.

Another Englishman, Armstrong by name, in 1887, came nearer the goal, and, had he persevered in his experiments, might have been successful. His method was to depress the wire netting into the surface of molten glass, by means of a heavy roller, and cover the wire in the glass by means of a following roller. He had the germ of the correct idea, but because of inadequate machinery, and other reasons, he stopped short, and failed.

In 1888 a German, named Tenner, patented a process that operated satisfactorily for small sizes, but, as the demand for wire-glass is for large sizes, the invention was not a complete success. His method was to roll a sheet of

molten glass quite thin, to lay on this a wire netting heated red hot, and to pour on another thickness of glass and roll it, after which the whole was subjected to hydraulic pressure. It was this last requirement that limited the size, as it was found impracticable to press over two feet square.

Another German patent (Sievert, 1882) produces the same result, though it is a better process than Tenner's, inasmuch as only one rolling of the glass is required, the hot wire netting being supported by the corrugations of the bottom of the mould.

The Shuman patents, for there are two of them, simultaneously issued under date of September 20, 1892, are the only United States patents granted for wire-glass up to that time, and constitute one of those rare instances of a process springing full-fledged and practical in a very short space of time to a most profitable and useful business. For the invention of a practical method of making wired glass, Mr. Shuman received the John Scott legacy and premium medal from the Franklin Institute in Philadelphia, in 1893.

In the Shuman process four rollers are used upon the molten glass, so arranged as to pass over in succession, without waste of time, the hot wire being fed in automatically between the first and second rollers. The wire netting is heated very hot, being at the time of incorporation within a few degrees of the temperature of the melted glass. A very long, cast-iron table is set in the floor and heated by gas flames, so that it will not chill the glass. When all is ready, a large ladle of molten glass is withdrawn from the blazing furnace, and carried between two workmen to the table, where it is tipped up and poured, in such a manner as to distribute its contents well over the table. Then the vehicle on the table, with its four rollers,

which have also been kept hot, is rolled from the end of the table, along a little track.

Roller No. 1 smooths and spreads the glass so that it presents a level surface. With and before roller No. 2 comes the red-hot netting, which slides down an inclined iron table and is pressed deep into the glass by the corrugations with which this roller is furnished. Roller No. 3 serves

FIG. 79.

to smooth over the glass and cover the wire, while roller No. 4 prevents the glass, which tends to become plastic at this stage, from curling up behind roller No. 3, and also assists a further smoothing of the glass.

The next process is the annealing, which serves to toughen the product. After this the glass requires only trimming to standard size to be ready for the market. As it is both inconvenient and difficult to cut both glass and wire in trimming, the wire introduced is of the size of the completed product, and the trimmer simply cuts the glass down close to the edge of the wire.

Sometimes it is desired to corrugate the wire within the glass, and this is readily done by making the ribbed surface of roller No. 2 with undulations that depress the hot wire more at some points than at others. The rolls are very heavy, being made to deliver a pressure of fifty pounds to the square inch. The wire netting used varies in mesh from a quarter-inch to three inches. The medium sizes are most in demand. The regular sizes of glass made by this process run up to two by seven and three by eight feet square. The thickness of the glass varies from three-sixteenths to three-eighths of an inch for common purposes. For special uses it is sometimes made an inch thick. The lesser thickness can be rolled in eighteen seconds, the three-eighths glass requiring twice that time. The difference in thickness is obtained by adjusting the height of the track that bears the rollers.

When it becomes necessary to cut the glass where it is wired, the method is to use a diamond, and break the glass, as would be done with any other glass, and then to work the glass back and forth until there is room to introduce a thin-bladed, fine steel-tempered saw, with which the wires can be cut. This is rather tedious, but it is an operation that does not have to be performed except in special cases.

The wire netting used is preferably a good grade of annealed steel. Before heating it is washed in benzine, then wiped and polished by being passed between rolls covered with bristles and buffing-rolls covered with flannel. Being thus rendered perfectly clean, it is fit to be impressed in the glass.

One of the advantages of this wire-glass is that it may be made thinner than other glass intended for the same use, as in roofs, since the wire gives greater strength. This not only lessens the cost, but removes a considerable portion of

weight, an item of importance in large roofs. It is not readily damaged by vibration, and it is hail-proof. Its strength is especially valuable when a bed of snow has to be supported, and it catches and retains falling articles, that would shiver any other sort of glass. Where glass is used protected by a wire screen it is practically impossible to keep the under surface of the glass clean, and it shortly becomes clouded and obscure, and never admits the amount of light that is to be had from the thinner and more easily cleaned wire-glass. As it becomes better known it will no doubt come into a variety of new uses, such as for port-holes and deck-lights in vessels, and for sky-lights in dwellings and business buildings.

MACHINE-MADE WATCHES.

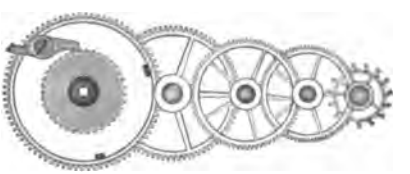
The Simple Mechanical Principles which are required in the Manufacture of Modern Time-Pieces.

THE cheapness and high grade of American watches long since ceased to be a marvel with the people. They simply buy them and use them, glad that they are both good and cheap, and only occasionally does some inquisitive individual, usually a boy, pull his watch to pieces to see how it is made. The real wonder about these tiny machines is that people know so little about them. Every farmer understands his mowing-machine; every printer knows the parts of the presses he uses; every woman learns something of the mechanism of her sewing-machine; yet, though nearly every person carries a watch, there are comparatively few who understand how they

work, and why the winding of a tiny spring for fifteen seconds should keep the hands moving for nine thousand times fifteen seconds.

Every one who aspires to know something of mechanism should acquire a knowledge of the principles on which time-pieces operate, and to this end a brief description is given here. The first thing to be borne in mind is that what is required in a watch is simply some mechanism that will keep going, and turn pointers around on a dial at an even speed. The simplest mechanism that will do this is the best. Some form of power must be used, for no machine will do work without power. A spiral spring has been found the most convenient form of motor, and it is given power by the daily act of winding it up. In order to make this unwinding of the spring take up as long a period of time as possible, what is known as the train of wheels is used. This is shown in Fig. 80, the wheels being arranged

FIG. 80.



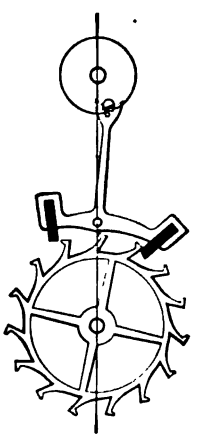
THEORETICAL WATCH-TRAIN.

in a line, for the sake of clearness, instead of crowded together, as in a watch, to save space. In the centre of the large wheel (Fig. 80) we see a little square post which the watch-key grasps when we wind it. Turning this post or arbor tends to wrap the spring around it, and when the spring is wound, it is held in its case—or barrel, as it is called—by the pawl which we see stopping one of the sharp ratchet-teeth in its periphery. In its endeavor to unwind,

the spring exerts a pressure of several ounces against this pawl, and, as the pawl is fast to the body of the wheel, the tendency is to make the wheel turn around, which is what it does. The wheel would turn around and allow the spring to unwind even more rapidly than it was wound up if it were not checked by delaying mechanism, which we shall describe further on. At present we must trace the motion through this train of wheels. At the centre of the second, or next to largest wheel (Fig. 80), we see a circular spot that represents the end of the pinion. This pinion is a little toothed axle fast to the large toothed wheel, of which it forms the centre. The teeth of big wheel No. 1 engage the teeth of the pinion of wheel No. 2, and thus drive No. 2 as many times faster than No. 1 as the big wheel is times larger than the pinion. If there are seventy-eight teeth on the big wheel, and ten teeth on the pinion, the second wheel will have about one-eighth the speed of the first. In like manner the second wheel acts on the third, and the third on the fourth, so that the third wheel revolves sixty times as fast as the first, and so on. Having now reduced the speed of the wheels sufficiently, we must next use a regulating machanism to check the motion of the whole train, which would still be entirely too fast for our use if left to run, checked only by the friction of its bearings. The mechanism we make use of is the escapement, which is partly shown in Fig. 80, as driven by the fourth wheel, but better in Fig. 81. This escapement-wheel we see has odd-shaped teeth, so made that the wheel can only turn around as the fork above it is worked or oscillated, so that the black teeth or pallets rise alternately, allowing one tooth of the escapement-wheel to escape at every motion. Thus this fork answers the same purpose as the pendulum of the clock, and the rate at

which the pendulum or fork allows the escapement-wheel to turn determines the rate of the watch. As it is impossible to use a pendulum in a watch that is required to go in any position, it becomes necessary to use other means to oscillate the fork. We can see how this is accomplished by consulting Fig. 82, which gives a view of the principal parts of a Waltham watch. Here we find the train of wheels differently grouped, but still arranged the same as to working. On the bottom of the cut, on the right, is the escapement-wheel, commonly shortened in name to escape-wheel or scape-wheel, and its fork is nearly hidden under the balance-wheel. It is this balance-wheel and the hair-spring, which we see curled up in its centre, that determines the oscillation of the fork. When the pressure of the main-spring makes itself felt through all the train of wheels, and turns the escape-wheel as far as it will go, it moves the fork to one side, thus partially winding up the hair-spring. Then a tooth of the escape-wheel escapes or slips by, and the hair-spring being released whirls the balance-wheel and turns the fork the other way, admitting another tooth of the escape-wheel, when the main-spring again comes into play, and the operation is repeated until the watch runs down. The balance-wheel is kept turning first one way, then the other, as it alternately takes its impulse from the main-spring or the hair-spring. The main-spring really furnishes all the power, setting the hair-spring every time, so that it may give a recoil and bring the fork back to place when the

FIG. 81.



ESCAPE-WHEEL AND FORK.

escape-wheel escapes. On the periphery of the balance-wheel will be observed a number of small screws. These are useful in regulating the watch to temperature. At

FIG. 82.

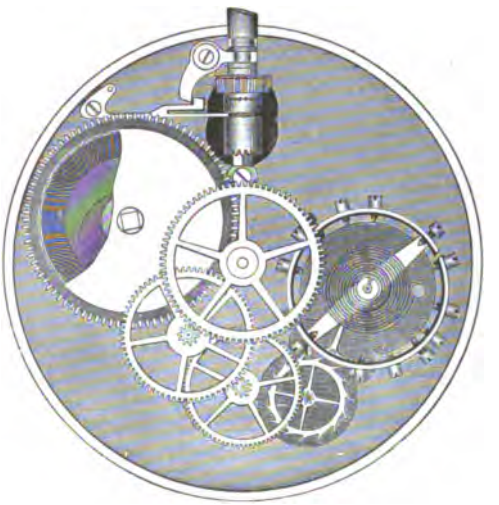
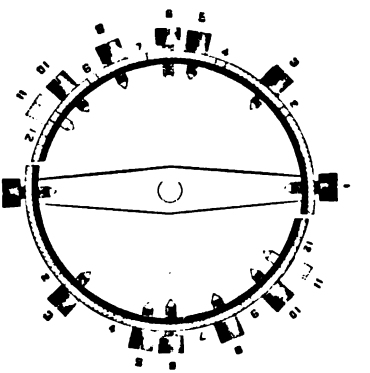


DIAGRAM OF THE PRINCIPAL PARTS OF A WALTHAM WATCH.

Fig. 83 will be seen a balance-wheel arranged with what is called the compensation balance, which was invented more than a hundred years ago. It will be observed that the rim is cut in two parts, which are maintained in position by a cross-piece. The black part of the rim is made of steel, the lighter part of brass, and being firmly fastened together a result is obtained that causes the balance to maintain the same speed whether the temperature is hot or cold. As the usual vibration of a balance-wheel is at the rate of eighteen thousand an hour, it can be seen that a slight expansion of the rim by heat would slow down the watch materially, while exposure to cold would make it

run fast. In the compensation balance, however, the brass expands faster than the steel, and tends to make the rim curl in with an increase of temperature, so that when it is hot the watch is inclined to run fast instead of slow, which would otherwise be the case. This tendency of the compensation balance to run fast when heated must be made to exactly balance the tendency which exists in the hair-spring to slow down because of lost elasticity under heat. When this is properly done we have a watch that will run accu-

FIG. 83.



THE COMPENSATION BALANCE.

rately at all common temperatures. The small screws in the balance-wheel may be set at any of the points numbered from 1 to 12, and by shifting them an adjustment of weight is obtained that causes the balance to throw in and out the exact weight required to alter the centrifugal force to meet the requirements previously stated. If it is found that an increase of twenty-five degrees in temperature causes the watch to lose seven seconds an hour, screw No. 3 might be moved to position No. 11, adding to the weight of the part of the rim that curled in with the heat, and causing the

balance to travel faster, since the shifted weight would under increase of temperature be nearer the centre, and exert less centrifugal force.

Another device is provided to adjust the speed of the watch when it is found to vary constantly in one direction. It is the lever or pointer on a scale which we move towards S to make the watch go slower, or towards F to increase its speed. This operates by increasing or lessening the tension on the hair-spring, to which it is attached.

Referring again to Fig. 82 we see at the top the winding mechanism that has replaced the old-fashioned key. Turning the winding post at the top serves to turn the barrel that carries the main-spring, through the medium of a toothed wheel called the crown-wheel, which is not here shown.

The fourth wheel of the train, seen at the bottom of Fig. 82, carries the seconds-hand (as it is properly called to avoid confusion with the more familiar adjective second-hand, associated with worn-out furniture or machinery). The second wheel of the train, called the centre-wheel, because of its location, revolves once an hour, carrying the minute-hand. In order to drive the hour-hand, two other wheels are required. These are not shown, as they would complicate the drawing, but it is sufficient to state that they act like the other wheels of the train, and that the one that bears the hour-hand is set on a collar, so that it may revolve about the same centre as the minute-hand underneath it, without either interfering with the other's motion.

It will be noticed that in each case two wheels are used to cause the difference of movement between one hand of the watch and another. One wheel would do, if proportioned as one to sixty, but if thus directly connected, the hands would have a reverse motion on the dial, two turn-

ing to the right, and one to the left, or vice versa. This has to be prevented by the use of two wheels, as the public would find it hard to grow accustomed to a watch that measured its minutes or hours backward.

There are other pieces and parts in a watch, but they are non-essential to an understanding of the principles on which it operates to maintain a regular speed. There are the jewels, or bits of ruby, that are turned in a minute lathe, and which serve as hardened bearings for the parts that are subjected to most friction and wear. A watch made without jewels can be sold for a dollar, and will keep tolerable time for a year or two. Stem-winding watches have a setting mechanism, operating from the stem. A small sliding or shifting lever is pulled from the side of the case, or the stem itself is shifted by pushing it in, and this serves to put out of gear the mechanism for winding, and bring about a connection with the centre wheel, bearing the minute-hand, which being set only friction-tight, may be adjusted either way without affecting the main-spring.

There is very little difference in the mechanism of the leading makes of watches, except in the escapement. This has been made in a great variety of forms, though the one here described is probably the most common. It is called the anchor-escapement, from the form of the fork. The name lever-escapement is also applied to this form. Another form is called the cylinder-escapement, and in this a cylinder takes the place of the fork, having points which engage the escape-wheel. The crown- or verge-escapement, also named the vertical escapement, has the escape-wheel mounted at a right angle to the train of wheels.

Large mechanical ability and a natural capacity for that sort of thing is requisite to the designing of a watch, and still more so to the making of the machines used in watch-

making. We no longer have the old-fashioned watch-makers, men who could make about one watch a year between the times they attended to customers in a little jewelry store. Superintendents of watch-factories and a few others are the only men who understand watch-making in all its details. The workmen are taught but one branch of the work, and kept at that, in order to arrive at the highest degree of skill and speed in that one thing. As a consequence only a few get to know the whole trade. Some of these few exhibit a degree of special training that is remarkable. The story is told of a superintendent in one of the leading watch-making establishments of the country who, on being shown a steel ball designed for use in a bicycle bearing, and requested to note its accuracy, jocularly remarked, "Why don't you make them round?" "I guess it couldn't be made much rounder," said the maker of the ball. After some banter, the man of watches took out his lead pencil and marked three spots, and offered to wager that they were below the radius of the rest of the ball's surface. Recourse being had to a very accurate micrometer, it was found that the spots indicated by the watch-factory superintendent were each about $\frac{1}{10,000}$ of an inch low, showing the marvellous sense of touch and accuracy that he had acquired in dealing with small things. It is the development of genius and accuracy of this sort that has made it possible to produce a watch of high grade that will retail for ten dollars, and very fair watches for four or five dollars each.

PROGRESS IN PRINTING.

The Development of Web Perfecting Machines for Daily Newspapers—Type-Setting and Line-Casting Machines.

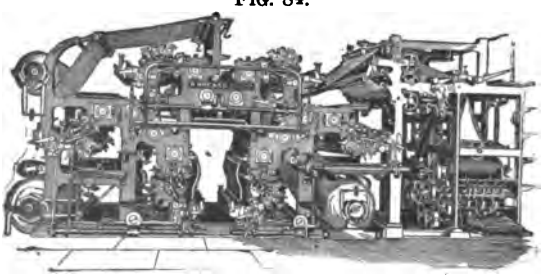
In no other trade has there been more manifest improvement in methods and results for the past twenty years than in the art of printing. The invention of movable types was made about the middle of the fifteenth century, and is generally spoken of as the invention of printing, since it made cheap printing possible. From that time up to 1800 there was little progress in the methods of work employed, though the printing of books became common, and there was established a considerable number of newspapers. About the beginning of this century, Napier invented the cylinder press, and steam was shortly applied to these machines. Since 1830 improvements have been rapid, and as the demand for cheaper literature grew the machinery has been perfected to meet the want, until today every large city in America has a press that will print from five to even fifty miles of paper in an hour, and ingenious machines that almost seem to think as they set up a hundred thousand types in a working day of ten hours.

The quality of the printing executed has improved as fast as the quantity. This is largely owing to the introduction of beautiful coated papers which are now produced as cheaply as were the rag papers on which newspapers were printed thirty years ago. The delightful half-tone pictures also have had a large share in the improved appearance of printing. These are fully treated of in the chapter on photo-mechanical processes.

Let us first consider the improvements in printing-machines. Most prominent among makers in America has

been Richard Hoe, and after him Andrew Campbell, Taylor, Potter, Cottrell, etc. Hoe, Campbell, and Taylor each introduced cylinder newspaper presses, before the Civil War, that would print one thousand papers an hour on one side, or by straining could be made to produce nearly double that speed.

FIG. 84.



HOE'S SEXTUPLE PERFECTING PRESS.

These machines were so well designed that the two former are manufactured to-day with few variations from the early patterns, and can be found in thousands of country printing-offices. With the war, newspaper circulations increased, and publishers demanded faster machines. Both Hoe and Taylor met the demand with double-cylinder machines, in which the bed of type was made to pass under two impression-cylinders at a single travel, so that double the work could be done with them. By making the machine quite large and heavy, it was possible to print both sides at once, on what is called the turn-and-cut principle, so that these presses really quadrupled the speed of the single cylinders, turning out usually two thousand four hundred perfected papers an hour, where the single cylinder printed but one thousand two hundred on one side only. Soon, however, the New York and Philadelphia papers began to break these machines to pieces trying to

get out of them double the speed they were designed to furnish. Then Hoe came to the rescue with four-, six,- eight-, and even ten-cylinder machines which increased the output in proportion to the number of cylinders, so that a ten-cylinder press was capable of turning out fifteen thousand to twenty thousand papers, under favorable circumstances. These machines were regarded as wonders, and they were wonderful in many respects. On a big central cylinder were wedged the pages of type, secured by ingenious devices in "turtles" to prevent the letters from being flung out by the centrifugal force of rotation. With the best of them some types were always sure to work out, marring the print. Around the central type-cylinder were arranged the impression-cylinders, to each of which a feeder supplied single sheets of paper that were carried around the impression-cylinder and printed as the type came around. If one of the ten feeders accidentally allowed a sheet of paper to go in crooked, it was very apt to jam up the press, and stop the whole machine. Further, the machine was very large, and required the attendance of about fifteen men. It cost more to print ten thousand papers in this way than it did to print them on single cylinders, the only gain being the saving in time, the essential thing in the printing of newspapers. It was evident that a better machine would have to be invented. About this time Walter began to build rotary web presses in London, printing from the roll of paper. Hoe and Bullock introduced the same principle in the United States, and the machines began to come into use early in the seventies. They would not have been wholly successful but for the invention, about this time, of a method of curving stereotype plates. This made it possible to print from a cylinder without making direct use of the type, and with a roll of

nearly endless paper passing around a cylinder so as to come in contact with another cylinder on which were clamped the curved stereotype plates, it then became possible to print at railroad speed, the limit being set by the rapidity with which the paper could be cut and folded. Hoe's firm for a long time controlled the market in this line of presses because of a patent folder that was about three times as speedy as any other that had been devised. In the ordinary types of folders, there is a dull knife that strikes the printed sheet of paper, doubling it, and thrusting it between two rollers so rotating together as to draw in the sheet so doubled. This dull knife has an up-and-down motion, and will not work satisfactorily at a faster speed than seven thousand an hour. Hoe devised a plan for mounting three of these dull knives on a cylinder, so that three doubling blows might be delivered to the paper every time the cylinder revolved. This secured about three times the speed of the old folders, and the patent was worth a great deal of money to the Hoes, as no other maker was able to build as speedy presses as these for a number of years.

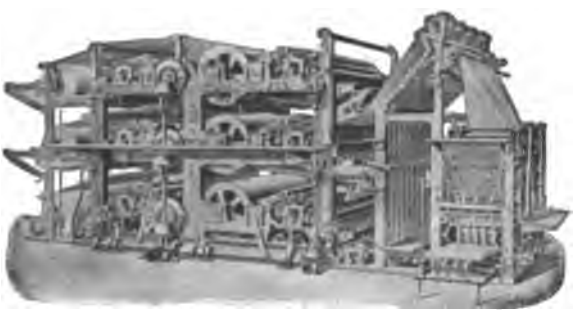
Within a few years past the firm of R. Hoe & Co. have introduced a variety of valuable improved machines. Among these may be mentioned an electrotype perfecting press, with cover-machine, paster, wire-stapling device, and folder, designed especially for printing illustrated magazines and periodicals. It is really two presses coupled together, one being for the body of the magazine, the other serving to print the cover. The folder and other devices bring the printed paper together and deliver the whole bound ready for delivery. The speed for thirty-two-page periodicals is ten thousand an hour, smaller sizes being proportionately faster.

A somewhat similar machine is made by the same firm for printing coverless illustrated periodicals, at a speed of four thousand to eight thousand an hour, doing fine work.

Hoe's newspaper perfecting presses are made in all sorts of sizes and combinations. The speed is practically limited to twenty-four thousand an hour, but by doubling and quadrupling results as high as ninety-six thousand an hour are obtained.

Walter Scott has obtained over a hundred patents within a few years, and manufactured a most interesting line of fast printing machines. Among them are many cylinder

FIG. 85.



WALTER SCOTT AND COMPANY'S LARGE INSETTING NEWSPAPER PRESS.

presses arranged to print from the roll, also double cylinder machines for printing both sides of the sheet before delivery. One of his flat-bed single cylinder machines prints from the roll, on both sides of the sheet, and delivers it folded at a speed of three thousand six hundred an hour, which is the greatest amount of work ever accomplished with a single cylinder machine. He has also designed a series of magazine presses, designed for fine work. He makes one that delivers completed almanacs at a speed of from eight to fifteen thousand an hour. His rotary web perfecting

newspaper machines operate satisfactorily up to speeds of seventy-two thousand an hour. A number of other firms are now making fast newspaper presses.

In the development of presses feeding from the roll, for job printing, Kidder, of Boston, and Eckerson, of New York, have been prominent. Kidder has devised a series of machines for special work, printing from type forms on flat beds. Cox, of Battle Creek, Michigan, struggled with the problem of printing newspapers on both sides from a web of paper, using type-forms from a flat bed. He finally succeeded, and has placed a press of this sort on the market that prints four thousand five hundred perfected sheets an hour, and dispenses with all stereotyping apparatus.

Machines designed to supersede the compositor in type-setting have been agitated for some thirty years past. They are of two classes, either composing the type, as in hand setting, or composing a line of matrices from which a solid bar, or linotype, is cast. Of the first kind the Thorne and Empire machines are successful examples. The Thorne has an upright cylinder on top of the machine, containing channels for the type. The operator manipulates a keyboard, and each touch of a key releases a type from its channel, and it slides by gravity to its place in the line. The lines are pushed out into a galley and justified by an assistant. Dead type is distributed automatically by being laid in the top of the type cylinder. Each type being differently nicked, and each style of nick cor-

FIG. 86.

THE THORNE TYPE-SETTING MACHINE.

responding to the form of a type-channel, the type all fall into their appropriate channels as the cylinder carrying them comes around.

The Empire is somewhat similar, but employs a separate machine to do the distributing, the type being pushed into little trays and carried by a boy to the composing machine.

FIG. 87.

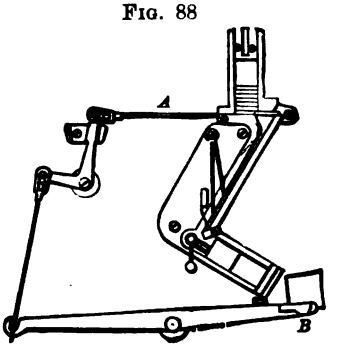
THE EMPIRE TYPE-SETTING MACHINE.

At the top of this machine are three cases, containing eighty-four channels, each in a separate cradle with glass fronts. The cradles are tipped up so that the type in the cases is all in view of the operator through the glass fronts.

Behind the bottom of each channel of the case is a steel

pusher, *A*, which the depression of the corresponding key *B* will force through the slot at the bottom of the case against the foot of the lowest type in the channel, which it will force forward, out of the case. The key being released, a spring withdraws the pusher, and the row of types, under their own weight and that of a free slug, falls to the bottom of the channel, leaving the next type in position to be

FIG. 88



THE EMPIRE'S METHOD OF RELEASING THE TYPE.

forced out by a pusher when its key is again touched. As soon as the key is released the corresponding type drops or slides foot foremost down the glass to its place in the line. A cam running in a race drives each letter as it drops, and the whole line, ahead, keeping a place continually open for another type, and pushing the line toward the justifier. That individual holds in his left hand a little device called a grab, adjusted to the required measure, and draws the needed length for a line into the upper end of a galley that takes the place of a composing-stick. Convenient to his hand are a lot of thumb-pieces, which when pinched by the justifier leave a space in his fingers, and with the different thicknesses of these he spaces out or justifies his

line, at the same time reading it and correcting any surface errors.

Other machines, as the Lanston monotype, dispense with distribution by casting new type for each setting. When the type is dead, it is simply thrown into the melting-pot.

Two successful machines on the line-casting principle have been introduced, the Rogers typograph and the Mergenthaler linotype. The typograph operates from a keyboard, the matrices being assembled for casting, and returned to position by raising a hinged frame which allows them to slide back to place.

The Mergenthaler linotype machine is in use in the leading newspaper offices of the world. It is not properly a

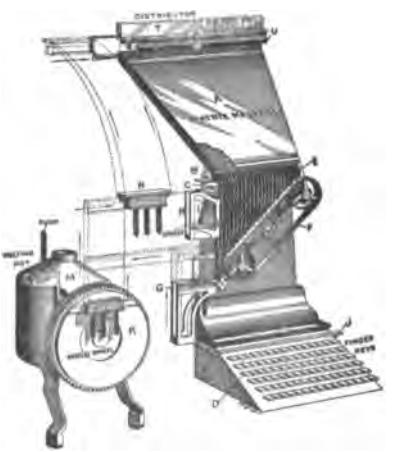
FIG. 89.

THE MERGENTHALER LINOTYPE MACHINE.

type-setting machine, but produces and assembles, side by side, metal bars or slugs, each of the length and width of a line of type, and having on the upper edge the type characters to print an entire line. These bars, having the

appearance of solid lines of type, and answering the same purpose, are called linotypes. When assembled in columns side by side, they constitute jointly a form, presenting on its surface the same appearance as a form of ordinary type, and adapted to be used in the same manner. After being used, the linotypes are returned to the melting-pot to be recast into other lines, thus doing away entirely with distribution. The machine contains a large number of small

FIG. 90.



THE LINOTYPE MECHANISM.

brass matrices, representing the different letters and characters. These are stored in the matrix magazine shown in the accompanying cut. When one of the finger-keys, as D, is depressed, it permits a single matrix, bearing the corresponding character, to fall out of the mouth of the magazine, and downward through channel E to an inclined belt, F, by which the matrices are carried down one after another, and delivered into the slotted assembling block G

in which they are set up or composed side by side in a line or row. A stationary box, H, contains a series of spaces, I, and a delivery service connected with the finger-bar J, by which the spaces are discharged and permitted to fall into line at their proper places. When enough matrices and spaces are assembled in the block G to complete one line of print, they are transferred, as shown by the dotted lines and arrow, to the face of a vertical mould-wheel, K, where they form the face or top of a mould. Molten type-metal being forced into this mould from the melting-pot M, by the action of the pump, a slug or linotype is cast bearing the characters of a line on its face. After the assembled matrices have thus answered their purpose in front of the mould, it is necessary to distribute them and return them to the magazine, from which they are again in due time discharged in order for use in succeeding lines. To accomplish this restoration to place the matrices are lifted from the mould, as shown by the dotted lines and arrows, into contact with the plate R, on whose lower side they are suspended by little grooves. This plate then rises, as indicated by dotted lines, lifting the entire line of matrices to the distributing mechanism at the top of the magazine. The spaces remain behind when the matrices are lifted to the distributor, and are transferred laterally to the box or holder H, to be used again.

It must be borne in mind that all these operations proceed while the compositor goes on working the keyboard, very much as he would run a typewriter. He rattles off a line, pulls a lever, and the machine does the rest automatically. The speed is ordinarily about four thousand ems—or some ten thousand letters—per hour, though double this has been accomplished as a matter of record. Among the conveniences of the machine may be noted the

fact that the length of line may be altered by changing the mould, and that by using a mould of larger size as to width, extra space may be obtained between the lines, which are thus leaded automatically. In order to make corrections the method is to throw away the lines containing errors and substitute others correctly composed.

While the Mergenthaler machine just described has proved entirely satisfactory for newspapers, it does not produce a face satisfactory to magazine publishers, and such continue to set their type by hand or use such machines as the Empire. There is a foreign machine, invented by a Catholic priest, Father Calendoli, which is said to distance all the machines in use. The keyboard includes fifteen alphabets, each of which is arranged in a square. The order of the keys in one square is made very favorable to the spelling out of a number of common words and combinations. The order of the keys in the next square is such as to facilitate the spelling of another set of words, and so on through the fifteen alphabet-squares. The capitals and points are arranged in a long row, the more common ones being repeated. Thus, letters are distributed over the board according to the frequency of their use. The object of this is to enable the operator to manipulate the keys as the piano is played—with all ten fingers. He can do this because such words as "write" are to be found with their five letters practically in order, as wr^{it}e, or w$_{\text{ri}}$t^{e}, or wri^{t}e—always continuously from left to right, so that the five can be rattled off with rapidity. The keys are connected by electric wires so that they move little magnets that pull a slide and release a type from one of a series of upright channels, when it slides down to its place in the line.

The arrangement is such that the type represented by the key first struck is sure to reach its place before any letter released later can get there. The speed claimed for this machine is fifty thousand letters per hour, which is too great for credence. Superior operators on other machines do not set over ten thousand letters per hour, and if this piano-playing idea proves to add fifty per cent. to the speed it will have done all that can reasonably be expected of such a system. It remains to be proved whether the gain in the arrangement of the keyboard is a real one, or whether there is as much lost by looking up and reaching for far-off keys as is saved by the convenient arrangement of letters when found. If the idea prove practical it should become in time a feature not only of all type-setting machines, but of typewriters and similar keyboard machines.

A German type-setting machine has just been announced from Berlin under the name "plectrotype." It consists of a form of typewriter that punches holes in a paper tape. The tape may then be read for corrections, which are made by hand, after which the tape is fed to an automatic type-setter that selects the proper types by means of electric currents set up by wires forming connections as they pass the perforations in the paper. The machine is wholly automatic, requiring but one person to attend several of them—put in dead type for distribution, take away composed type, and keep up the supply of copy-tape. It has five times the speed of keyboard machines, composing twenty thousand ems an hour. If this invention proves to be what is claimed for it, editors will in time set up their articles on the typewriter, read and correct the copy-tape, and pass it on to the composing machines, dispensing entirely with the compositor.

Paul F. Cox, of Battle Creek, Michigan, has recently designed a machine for setting type, in which the spacing of the lines is accomplished by using crimped spaces. The lines are simply set to the full width, or wider, and then subjected to a pressure which reduces the thickness of the crimped spaces so that the line is of the proper length.

General T. T. Heath, of Cincinnati, is the inventor of another machine, which he styles a matrix-making device. This has a keyboard, operating like a typewriter, to so indent the letters into a paper that the paper may be used as a matrix to make a cast from, as of a page at a time. This method has the advantage of utilizing the original punches, and thus securing clearness of outline for the letters, but it is obvious that the correction of errors must be a tedious affair.

Various improvements in type have appeared within a few years. What is called self-spacing type has proved a great convenience in table work and the like. It is so proportioned that there is no difficulty in bringing a word or figure in one line exactly below one in the previous line. This was not easy with other kinds of type, because of the great variation in thickness of the letters. The present year (1895) a new alloy for type-metal has appeared in the market that may create a revolution. A mixture of lead, tin, and antimony is now used, but this new alloy is said to be very much lighter and harder. The makers do not tell us what it contains, but it is presumed that aluminum is one of the components. It is so tough as to render copper-facing and electrotyping entirely unnecessary.

Color-printing has progressed as rapidly as any other branch of the business. The improvement in inks and paper has helped the production of beautiful effects. For

some years various experimenters have endeavored to produce illustrations in the three primary colors, so superposed as to give the effect of all the colors. This result has at last been attained, and is more fully described in the chapter on "Photo-Mechanical Processes."

PHOTOMECHANICAL PROCESSES.

The Development of the Art of Ornamental Illustrations in Connection with Printing, culminating in Three-color Half-tone Pictures.

THE term "photomechanical" is applied to any of the modern processes for the production of illustrations, as for books and periodicals, in which the work is done partly by photography and partly by machine or hand. During recent years photography has become a most important branch of illustrative work, and has been utilized to such an extent that wood-engraving has gone into a serious decline. The new processes have the advantage of being more accurate and more artistic, and of requiring less time and less money for their production.

There has existed much confusion of nomenclature among the various processes that have been devised for superseding engraving by hand, so much so that the International Photographic Congress of 1889 gave prescribed definitions for leading words in the trade, in the hope of regulating the matter so that the names used would have a definite meaning. This confusion of names came from a desire on the part of individual firms to impress the public with the idea that they had a process which was

better than that of others, and each one, to distinguish his process, gave it some high-sounding name, when in reality it was the same process used by others under a different name.

The Congress we have referred to adopted the following names: Photochromography, for the art of reproducing, by the printing-press, photographic images in several colors; photocollography, for the art of producing plates for printing by the gelatin process; photoglyphtography, for the production of photoengraved plates in intaglio, that is, with indented instead of raised printed surfaces; photoplastography, for those processes in which a plastic substance is so acted on by light and water as to change its form, in accordance with a negative, and become suitable for direct printing on paper; photoprint, for any print obtained by any one of the photomechanical processes; phototypography, for any of the mechanical processes of engraving that produce a relief plate that can be printed from with type.

While the above are the names which should be used principally, and which doubtless will be used in the future, yet, for the sake of a brief historical record of the development of these processes, it is necessary to revert to many of the old names.

The first discovery of which there is record was of a photoplastic process. It was about 1822 that Joseph Nicéphore Niepce produced a printing plate by coating a metal surface with a solution of bitumen, and exposing the same to the image in a camera, after which the parts not rendered insoluble by the light were washed away with oil of lavender, and an etching acid was used to bite into the metal beneath. In this process, rude as were its results, we have the leading elements of all the processes of to-day, the

later methods tending to perfect and beautify the work, but operating on the same general principles.

The next inventor who appears on the scene had an almost equally noneuphonious name—Mungo Ponton. In 1838 he discovered that gelatin was better than bitumen for making plates, and he produced the first photocollograph.

The last great discovery upon which the photomechanical art has been built up was made by Fox Talbot, in 1853. He discovered that a film made of gelatin treated with a dichromate, when dried at a moderate temperature and exposed to the light below a negative, could subsequently be used for printing on the principle used in lithography. Thus was produced the first photolithograph, the surface produced, after washing and drying, tending to absorb water and refuse greasy ink in the white parts, and to take ink and refuse water in the parts which it was desired to print.

Photocollography, or the gelatin process, owes it greatest development to Sir Walter B. Woodbury, who was the inventor of those improved methods commonly known as the Woodburytype, Woodburygravure, and stannotype. The Woodbury process consists in coating a glass plate with collodion and afterwards with dichromated gelatin. The plate being exposed under a negative, and washed in warm water, the soluble parts are removed, and the desired design stands out in relief. The gelatin film so made becomes so hard when dry that it can be impressed in a soft lead plate, forming an intaglio mould. Warm gelatin is then poured on the intaglio plate, a sheet of prepared paper being subjected to hydraulic pressure in such manner as to drive out the gelatin from the flat surfaces, and leave on the paper a gelatin image. The metal plate may then be printed from, after the manner of a copper-

plate, the tone or gradation depending upon the thickness of the gelatin at the various points.

The stannotype process is a cheapened form of the Woodburytype, an India-rubber solution, tin-foil, and rubber rollers being used instead of the lead plate and hydraulic pressure. It is printed from in the same manner as the Woodburytype.

The Woodburygravure was the last invention of the late W. B. Woodbury. It is an adaptation of the Woodburytype, producing a result in imitation of photogravure. In this process the unsightly margins are masked so that there is no serious amount of mechanical trimming to do later.

The Albertype or collotype process is one which has been blessed by a great variety of manufactured and high-sounding names. In this a piece of ground plate glass receives a film of dichromated gelatin and albumen. After receiving a second coat of gelatin, it is dried and exposed beneath a reversed negative, then soaked, hardened with alum, and dried. The plate so made may be stuck in plaster on the bed of a lithographic press, and printed in the ordinary manner. The heliotype, artotype, and indotint processes are slight modifications of the above.

For phototypographic printing a variety of fancy names are appended to the processes, but all of them are virtually one. A sheet of chromatized gelatin is exposed under a negative, the light that shines through making the contiguous parts of the gelatin film insoluble and incapable of absorbing water. The gelatin is next soaked in water to swell the soluble parts, or the soluble parts are washed away. In either case a mould can be obtained, in wax or plaster, from which an electrotype may be made for printing with type on any ordinary printing-press.

In phototypography, or process-work, as the last-described method is often loosely called, there are two common methods, the line engraving and the half-tone. The line method is that in which the picture appears in sharply defined lines, reproduced from a pen-drawing, a reprint cut, or the like. These are usually reduced in size by photography, a one-half reduction of a drawing going far toward hiding minor defects.

Half-tones present a surface of very fine dots, giving tones and shades of exquisite beauty, but exhibit no sharp lines of any sort. For these a glass screen is used in taking the photograph. This screen has a number of fine black lines ruled on it so as to cross. This ruling is done with a diamond point, and the closeness of the lines determines the fineness of the resultant picture, practice varying between seventy-five lines per inch for newspaper illustration and two hundred lines per inch for fine magazine reproduction. These lines on the screen being filled in with a fine black substance interrupt the light that goes to the negative, with the result that the image formed is all in dots that vary in size according to the amount of light that struggles through the screen at that point.

The latest and greatest success in photomechanical processes is in the department of photochromography. In 1865, Henry Collin, of England, suggested that if three photographs of the same thing were taken in red, blue, and yellow light respectively, and the plates made from the same printed in the same colors, one on top of the other, a picture printed in the colors of nature ought to result, since there would be combined all the primary colors. A number of inventors have struggled with the problem ever since, but the mechanical difficulties encountered have been so great as to delay success until the present year (1895).

For several years back the public has been informed periodically that the result had been obtained, but when the demonstration came it appeared that the experimenters were too eager to accept approximate results, and rushed before the public with an incomplete method. In May, 1895, however, the *Inland Printer*, of Chicago, contained two of these three-color pictures, produced by photographic half-tones, that are most artistic in appearance, and prove that the process is at last on a commercial footing. To make these pictures three negatives are used, the plates being color-sensitized by means of three different dyes, each of which absorbs one-third of the spectrum and reflects the other two-thirds. In photographing, color-screens are used to absorb those rays which are not wanted for a particular plate. Three half-tone electrotypes are made from the photographs so taken—one for printing in yellow, another for red, and a third for blue. As each plate has failed to receive the light of the other colors, if correctly made, the printing will be a reproduction of the original in the colors of nature. As a matter of fact, this result is not wholly accomplished, for though the three plates when printed approach in value a high-class chromo in forty or fifty colors, yet at the present stage of the art they fail to equal it, mainly because there are no inks in use of the necessary transparency. No doubt ink-makers will in time meet the demand. For the present the most that can fairly be said of these pictures is that they are better than any other three-color pictures that the world has yet seen, and certainly equal to the results obtained by the old methods where six or eight colors were used.

STEREOTYPING AND ELECTROTYPING.

The most Recent Processes in Kindred Arts that have contributed much to the Perfection of Printing.

THE duplication of printers' forms by stereotyping or electrotyping may be performed for any or all of several objects—the saving of the wear on the type in printing, the convenience of having the type released for other uses, or to secure several casts or plates that may be printed on different presses at the same time. Stereotyping is the ruder process of the two, and is used principally for daily newspapers, where time has to be saved. Electrotyping produces better results, and is usually adopted in the case of magazines and books.

Early printers tried stereotyping for the purpose of avoiding the errors that might creep into pages of movable type, kept standing and liable to squabbling or other derangement. Brass appears to have been the metal at first used for this purpose, impressions of the form being taken in loam moulds. About 1700 a German clergyman, Jean Muller, tried fusing the backs of the pages of type by resting them on a hot plate. In this way he secured pages of the New Testament that were proof against falling apart. About 1725 the plaster process of stereotyping was introduced, consisting in the use of a plaster-of-Paris mould, from which casts were made in type metal, with very fair results. This was the ordinary process up to the time when the paper process was invented, apparently by several individuals working independently. It has been somewhat improved by later users, and is the process commonly used to-day for all sorts of stereotyping. This

method derives its name from the use of a paper mould, formerly termed a flong, now commonly a matrix-paper, which is formed by pasting together several thicknesses of paper. This is laid wet upon the face of the form, and beaten with a brush until the softened paper sinks well into all the interstices of the form, making a clear impression of

FIG. 91.

SCOTT'S CASTING-BOX FOR CURVED STEREOTYPE PLATES.

the type. The whole is then squeezed in a press, and the matrix is well dried, after which a cast may be taken from it. A recent improvement in this provides the use of a rolling matrix-press. The form is simply laid on the bed of the press with the prepared matrix on top. Being run under a heavy roller it is quickly impressed, and may then

be steam-dried and cast. Until 1893 the matrix, being moist, had to be thoroughly dried before a good cast could be obtained. Since then a dry matrix-paper has been introduced, which is said to give good results.

In casting for daily papers, a curved plate is generally desired, and this is obtained by the use of a curved casting-box, as shown in the cut (Fig. 91). Within this the matrix-paper is simply curled into shape, and as the hot metal is poured in its weight presses the matrix-paper into correct form. When cast, the plate must be sawed, trimmed, and bevelled, after which it is ready to be clamped on the press. To such perfection has this process been brought that during the rush of getting off the last plates of a daily paper not more than ten or twelve minutes elapse between the time the form is brought to the matrix-press and the plate is on the press ready for printing.

For job-work the plates are usually cast flat, and may be screwed on to wood bases, though this method is going into disuse in favor of electrotypes.

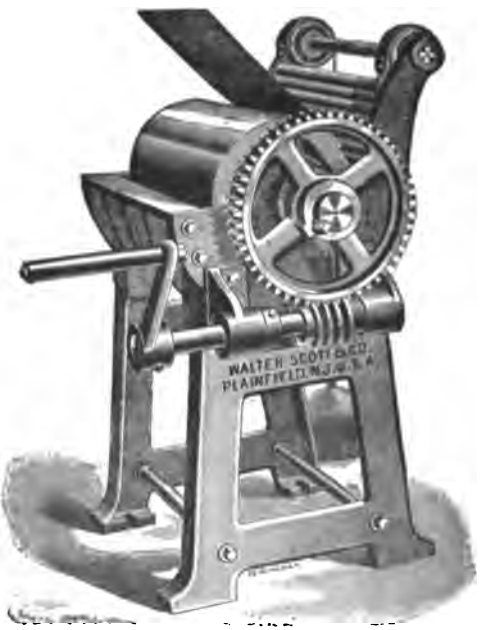
Electrotype plates are made on a different principle. In this process the first cast is made in beeswax. The wax is melted in a kettle and poured out on a flat plate called a moulding-case. When this moulding-case bears a film of wax about the sixth of an inch in thickness it is placed in the moulding-press. The form of type to be reproduced, having been dusted with black lead (plumbago), is laid face downward upon the wax surface and subjected to a moderate squeezing in the moulding-press. The wax matrix is next trimmed up on the edges and receives a thorough coat of plumbago. This matrix is then suspended in a bath containing a solution of sulphate of copper (rarely of nickel). A plate of copper is also suspended in the bath, and a battery or small dynamo is connected. Elec-

trical deposition of copper on the wax follows, and after some hours a sufficiently thick shell has been formed for use. This thin electrotype shell is then removed, washed, cleared of wax, and taken to a furnace, where it is sufficiently heated to allow a plate of tin-foil to adhere to the back. The shell next goes to the backing-stand, where it is laid face downward and a ladleful of electrotype metal is poured on to a thickness of about one-sixth of an inch. After cooling, this plate goes to various machines to be planed to a certain thickness, trued up on the margins, etc. It is then subjected to a critical examination, and trued up by hammering on the back, after which it is ready to be mounted on a block and printed from. It is often desirable to make corrections in electrotype plates, which may be accomplished by driving through a sharp punch, and inserting type to take the place of letters thus obliterated. The type are crowded in to the level of the face of the plate and cut off, so that they virtually become a part of the plate.

Walter Scott & Co. have introduced within a few months the electroplate bending machine shown in the illustration. The electroplate is introduced between the resilient steel plates shown in the cut, a press-board being put over the surface of the plate to prevent injury against the steel. The two are then drawn round by the cylinders between a series of small rolls hinged on chains at their ends, these rolls being close together. They travel over the surface of the steel plate, advancing forward at one-half the speed of the plate. This difference in speed is caused by the rolls that revolve between the steel plate and the concave back. These rolls are supported their entire length against the concave surface between which they pass as the cylinder is turned round. The edge where the

plate enters is slightly larger than the part where it comes out. Thus the electroplate is bent by a progressive uniform movement, and is supported in its weak or thin parts by the steel plate; in other words, the steel plate is bent by the machine, and incidentally, the electroplate.

FIG. 92.



BENDING MACHINE FOR ELECTROPLATES.

There is nothing very remarkable about either stereotyping or electrotyping processes, except the cheapness and excellence of the results attained by development of the mechanism. Stereotypes are made as low as half a cent per square inch, and electrotypes for a cent and a quarter an inch. Both of these prices are to large customers; in small lots the prices are higher.

SUGAR-MAKING MACHINERY.

The Mysteries of Vacuum-Pans, Triple Effects, Centrifugal Machines, Mixers, Defecators, Charcoal Filters, etc.

THE world's supply of sugar comes almost wholly from the sugar-cane, which grows most abundantly in Cuba and the Sandwich Islands. The sugar is obtained by expressing the juice, expelling the water therefrom by evaporation, throwing out the remaining molasses, and allowing the resultant sugar to crystallize. The theory is extremely simple, but the perfection which the mechanism has obtained within recent years makes the process appear complicated.

When the sugar-cane is brought to the mill it is dumped on a cane-carrier, which is nothing but an endless travelling conveyor, formed of wood slats or boards, carried by two endless chains. It is perhaps six feet wide in the larger sizes, and feeds the cane slowly to the cane-cutter, if one be used, such cutters being not absolutely necessary to the process, though a decided advantage. This cutter consists of two large corrugated rolls made of iron, but having steel rings on the face which are so cast as to present corrugations or undulations of surface of a depth of two inches and a length of six inches. These corrugations are so zigzagged that a piece of cane cannot pass through without being broken to at most six inches of length. Krajewski, Pesant & Co., of New York, control the market in these machines by virtue of a patent on the corrugations. About sixty per cent. of the juice is expressed from the cane in passing through the cutter.

The cane-mill—or sugar-mill, as it is less properly called—consists of three heavy cast-iron rolls, between

which the cane is passed, they being set about half an inch apart. The top roll is called the king-roller, the lower roll, to which the cane is fed, the cane roller, and the other lower roll the bagasse-roller. These rolls in manufacture are slightly scored by the lathe-tool, so as to prevent smoothness and cause them to grip the cane instead of sliding over it. The upper roll is the largest, and it is sometimes thirty-eight inches in diameter, though thirty-six is the common size. A guide-piece or returning-knife is placed between the lower rolls to turn the cane from the cane-roll so that it will pass over the bagasse-roll. The mill is driven by enormous gearing, and is made very heavy in all its parts, because there is no telling to what strains it may be subjected. The escaping juice flows into a tank below. If the juice is not thoroughly expressed by one crushing it is put through the mill again, after which it is thrown aside to be used as fuel to feed the flame under the boilers of the establishment.

The juice in the tank under the mill is in a quite impure condition, and is pumped through strainers to a higher tank from which it is fed by gravity to the defecators. This consists of a large open pan or pot, in which a small quantity of lime is thrown to assist in settling the impurities. It is slightly heated by steam, which coagulates the albumen. From the defecator the juice is drawn off in such a manner as to leave the scum and settlings behind.

The next process is the boiling of the juice to evaporate the water, which at this stage forms seven-eighths or more of the juice. The old method of doing this was to flow the liquid through a series of open pans set upon a furnace. Norbert Rillieux, of New Orleans, invented the vacuum-pan process, which is so much better that it has entirely superseded the other. It has been much improved, and

the type commonly used now is called the "triple effect," because three vacuum-pans are used. If four pans are used it is a "quadruple effect," or any number of pans above one is called "multiple effect." These vacuum-pans are really large cylindrical tanks, round-topped, and having a big pipe in the top for conveying the steam to the next pan. Inside is a huge drum, with seven hundred to one thousand copper tubes, each about two inches in

FIG. 98.

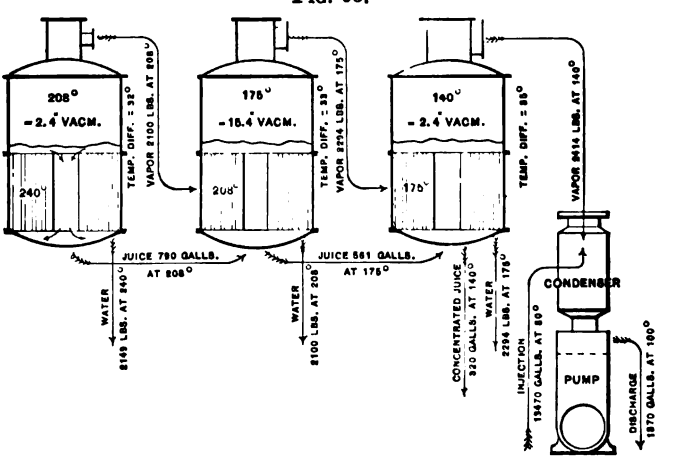


DIAGRAM OF THE TRIPLE-EFFECT METHOD OF EVAPORATION.

diameter. In the tubes and on top of the drum the juice circulates. In the drum and outside the pipes exhaust steam is admitted at a temperature of about 190° to 208° Fahr. See illustration. This would not be hot enough to boil the syrup were it not that a partial vacuum is maintained in that part of the pan in which the juice is admitted. In a vacuum water boils at a much lower temperature, so that 190° are ample to set the juice to steaming

and boiling. The steam that comes off the first vacuum-pan is led to the drum of the second pan, where it boils the juice brought in from the first pan. A better vacuum is maintained in the second pan, and therefore the steam—which has now fallen to 160° or 175°—is still sufficient to further boil the liquor. The steam from the second pan passes on to the third pan in the same manner, and here the vacuum is made as perfect as possible, partly by pumping and partly by condensing the steam. The juice is flowed from one pan to another by taking advantage of the difference in pressure, so that no pumping is necessary.

While there is no theoretical limit to the reduction in the consumption of steam due to increasing the number of vacuum-pans in a multiple effect, the practical limit is soon reached. The gain in economy from each additional vessel is a rapidly-falling quantity, and is soon overtaken by the extra cost, complication, and loss by radiation, which are practically constant for each addition, though partially compensated for by the reduced capacity of the condenser and air-pump, rendered permissible by the reduction in the volume of vapor discharged from the last vessel. This explains the apparent anomaly that the larger the number of vessels in the series, the smaller the condenser and air-pump required. In practice, with heating steam at five to ten pounds pressure, as common in sugar-works, triple effects are almost universally employed, having been found to be more economical than the double, and quite as satisfactory as the more costly quadruple effect. A type different from that illustrated has been used, having horizontal instead of vertical pans, with tubes about twelve feet long, provided with steam chambers projecting from the main shell. The steam is in the tubes, and the liquor surrounds them. The construction is

cheaper than the vertical, but less effective. Some French makers have graduated the size of the pans, giving increased heating surface as the juice increased in intensity, but the advantage gained has been so trifling that the idea is not copied.

It should be noted that the temperature differences of the triple effect are automatically adjusted. When first built, it was thought necessary to add valves, by which an attendant could add steam when and where he thought it necessary. This proved to be a mistake, as should a vessel from any cause fail to condense the vapor as fast as it comes forward from the previous pan, the vapor will accumulate and the pressure and temperature increase, causing a twofold correction.

Within a few years two new designs of triple effects have been placed on the market, the Yaryan and the Lillie. In both of these the leading idea is, instead of filling the heating tubes with liquor, to pass only a small stream through a considerable length of steam-heated tube, and as far as practicable to cause this liquor to form a thin film over the surface of the tube.

After passing through the triple effect, the juice, which is now sufficiently thickened to be called syrup, is clarified by further boiling and skimming, as there remain in it impurities that are more easily removed at this stage than before reaching the triple effect. The clarified syrup is then pumped to another vacuum-pan, where the final evaporation takes place. By this time it is so free from moisture that it forms a sticky mass that flows with great slowness and difficulty. At the bottom of the final pan is the strike-valve, which is a hole sixteen or eighteen inches in diameter, through which the pasty mass is drawn off, the operation being termed a "strike." The mass,

which is now a mixture of sugar and molasses, is passed into cooling cars, where the sugar begins to crystallize, and the longer it stands, up to a certain point, the larger will be the crystals. A mixer, having rotating paddles, is next employed to stir the mass, after which it passes to the centrifugal machines, and the molasses is entirely got rid of by centrifugal force, which throws it out while retaining the grains of sugar. The centrifugal machine has an outer case of metal, within which is a rotating basket, so perforated that the juice has a chance to flow away. The pulling of a lever starts the rotating basket, in which perhaps two hundred pounds of sugar have been placed, and it soon attains a speed of one thousand revolutions per minute. Three or four minutes of this rapid whirling are sufficient to remove all traces of moisture.

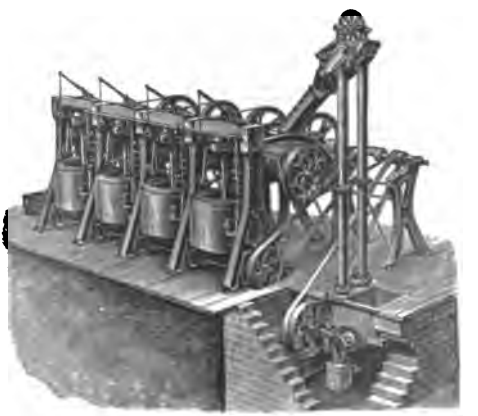
Sugar so made is nearly white in color, and in fit condition for immediate use, but fashion has ordained that it shall be refined or whitened, a process that rather detracts from the saccharine qualities of the sugar, but which renders it of more commercial value because it looks better.

The first process in the refining of sugar is to dissolve it in hot water in a cistern. The liquor is then pumped up into tanks called blow-up pans, where it is treated much as the juice was in the defecator. The liquor next goes through a series of five or six long cylindrical filters of animal charcoal and bone-black. Then it goes into a vacuum-pan to be evaporated, and later to a centrifugal machine, from which it emerges as the granulated white sugar of commerce. If loaf-sugar is desired, however, instead of going into the centrifugal machine, the syrup is poured into moulds, and allowed to cool. The mould of sugar is then run under a gang of small saws, set the distance apart that the lumps are to be. These saws first

cut the cake of sugar into slabs, then into sticks, and on the final cutting into lumps.

The making of sugar from beet-root is practised to some extent, though it has never been able to compete with the sugar-cane industry. The methods are numerous. Sometimes the beets are placed in bags and subjected to hydraulic pressure to remove the saccharine juices; sometimes centrifugal machines have been used to separate the crushed

FIG. 94.



CENTRIFUGAL SUGAR-MACHINES.

beet; sometimes the entire beet is macerated, and the juices expressed; but none of these processes are entirely satisfactory. What is known as the diffusion process has met with the most favor. In this system the beets are thinly sliced, and passed through a diffuser, that circulates them in water until the saccharine matter is removed without the nuisance of added pulp, which is the chief difficulty in the other processes. The beet-juice so obtained is then defecated, and subjected to a process of saturation with

carbonic-acid gas. The juice so carbonated then goes to a settling-tank. It may then be filtered and evaporated in much the same manner as the juice extracted from the cane.

The use of sugar steadily increases, though its future production as an industry is much clouded by trusts, politics, tariffs, and revolutions.

THE EMERY TESTING-MACHINE.

A Mechanism indicating with Equal Facility the Breaking Strain of a Hair or an Egg-shell and the Force required to break a Massive Steel Link.

THE great extent to which iron and steel now enter into the construction of large and valuable machines and structures has greatly increased the importance of accurately testing the materials used, in order that there may be no misconception of the strength of parts, with a resultant possibility of danger to those who come in contact with them. The margin between the breaking strain of a part or mechanism and the strains which it is liable to encounter in actual use is often ten to one—that is to say, machinery is designed to be ten times as strong as theoretically it need be to do the work. In machines like bicycles, however, where lightness is especially in demand, the factor of safety may be and is reduced to five to one, and even less. Some makers advertise that they test the cranks of their cycles to a strain of six hundred pounds. In starting a bicycle the ordinary man will apply a pressure of a hundred and fifty pounds on one of the cranks, so that the factor of safety in such a case is only four to one. In high

buildings, where time is sure to create some difference in the strength of the structural steel, and where the lives of hundreds of occupants depend upon its solidity, the factor of safety should be as great as eight or ten to one. The same is true of elevated railways, bridges, and other structures where accidents would be peculiarly disastrous and destructive to life.

It follows, of course, that engineers have always paid great attention to the quality and strength of their materials, and have tested them in the best manner known. Within the last fifty years a variety of testing-machines have been manufactured, all of which seem crude in comparison with the Emery hydraulic testing-machine. They were built like scale-beams or stout weighing-machines, and in some of the early forms the balance-weights were scrap-iron, which flew all over the shop when the specimen under examination broke. As it is usual to strain specimens to the breaking-point, it can be understood that dodging was one of the first requisites of a good workman with one of these machines. A feature common to all of them was the steel-yard balance, resting on a knife-edge. The best of these did very well for small work, and are so used all over the world to-day, but for large and heavy work they are inadequate, and when the knife-edges become dulled, they are rendered inaccurate.

It was this state of affairs which induced Mr. A. H. Emery to study out new lines for a machine equal to the demands of modern machinery constructors. To say that he has succeeded is putting it mildly. What the steam-hammer was in its day to the forger, so is the Emery testing-machine to the mechanical engineer of to-day. It will exert a pressure of one million pounds, and measure it with perfect accuracy, and the next instant crush an egg-

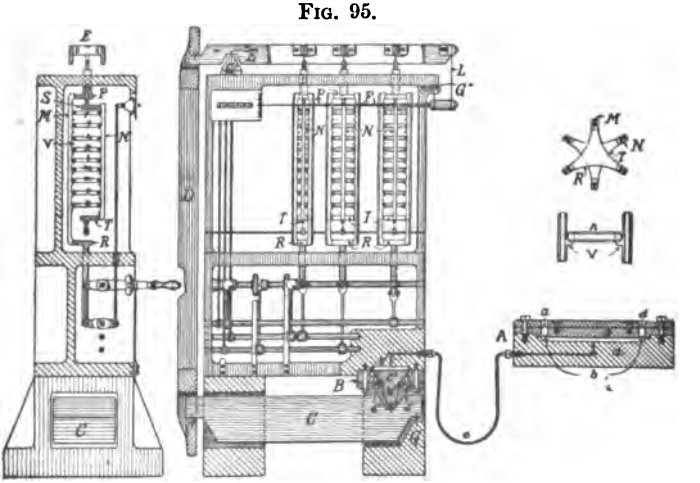
shell and record the minute power exerted. In a recent government test one of these machines pulled apart a forged iron link, five inches in diameter between the eyes, at a strain of seven hundred and twenty-two thousand eight hundred pounds, and immediately afterwards pulled a horse-hair slowly in two, registering the facts that it stretched thirty per cent. before breaking, and withstood sixteen ounces of strain. What other machine is there that could stand the rack of such enormous strains without deterioration?

William Sellers & Co., the owners of the Emery patent, have somewhat improved the machine since its first conception, and we will examine it in its latest form. Its essential peculiarity is the method by which the stress produced upon the piece tested is conveyed to the scale and accurately weighed by mechanism that is practically frictionless, and not subject to wear, and hence records every increase in strain without loss by friction. This is accomplished by the use of water in a flat-closed cylinder called the hydraulic support. The principle involved is this: If we take a cylinder of water standing on end, and place a weight upon an absolutely tight plunger on top of the water, and if we have a hole in the bottom of the cylinder whose diameter is one thousandth of the top aperture of the cylinder, upon which the weight rests, and if we then measure the pressure of the water at the little hole in the bottom, we have only to multiply it by one thousand to get the weight of the load on the cylinder.

The means by which Mr. Emery produced an absolutely tight cylinder operating without appreciable friction are very ingenious, and will be understood by examining the accompanying diagram of the weighing mechanism. *A* is the hydraulic-support cylinder, the white space represent-

ing water; *c* is the piston, and *b* and *dd* are thin sheets of metal. The piston rests on the lower sheet, and is secured to the cylinder by the sheets *dd*, which are flexible, allowing a movement of perhaps three thousandths of an

FIG. 95.



DETAILS OF WEIGHING MECHANISM.

inch, which is all the motion needed between a full load and no load. By this arrangement the fluid is entirely enclosed, and no packing is required, and the friction is all in the fluid. A tube connects the water-chamber of the hydraulic support with a smaller and similar chamber, *B*. The piston *c'* of this latter chamber acts through the block *H* against the first lever *C* of the scale, which thus receives a fraction of the load upon the piston *c*, of the large cylinder, determined by the difference in size between the two hydraulic cylinders *A* and *B*, which in practice is much greater than that shown in the diagram.

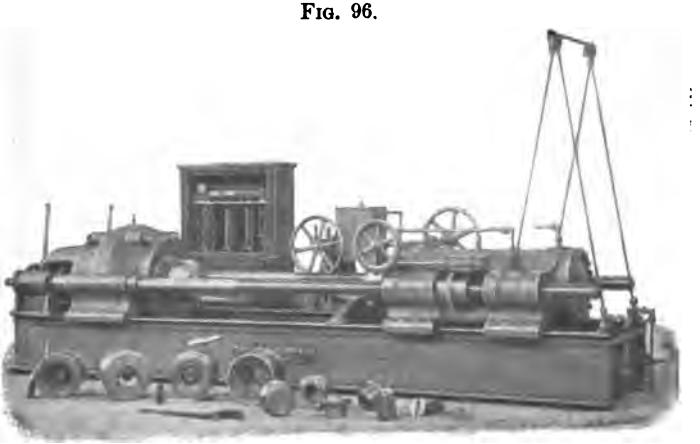
At the upper left hand of the larger figure in the diagram

will be observed a row of figures, and an upright scale marked by a long needle, *F*. When the hydraulic cylinders exert a pressure upon the first lever *C*, this pressure is communicated by the arm *D* to the lever *E* of the poise-frame. It will be observed that the lever *E* rests on a knife-edge like the long beam of any ordinary weighing-machine. From this lever *E* depend three weight-holders technically termed "poise-frames" and marked *N*. These have an upper cross-head *S* (see left figure) and a lower cross-head *T* united by three vertical bars disposed at equal intervals about the cross-heads. These bars are provided on their inner faces with short projecting brackets, *V*, having a horizontal surface and a bevelled surface corresponding with similar surfaces formed on the weights *h*, which are short cylinders or rings with bevelled edges. The weights are carried by the flat surfaces and centred by the bevelled surfaces. *M* is a weight-frame of similar construction, for carrying the weights when not in use. This weight-frame can be thrown in and out of use by operating the hand-lever coupled to the rod projecting from the cross-head *R*. The brackets on the weight-frame bars are differently spaced from those on the poise-frame, and when the weight-frame is at the top of its stroke, it carries all of the weights clear of the poise-frame; a small movement downward transfers one weight to the poise-frame, the bevelled surfaces on the brackets centring the weight if it becomes displaced sideways by a too sudden movement; a further movement transfers another, and so on. In the diagram the weights *f* and *g* are shown carried by the poise-frame and *k* by the weight-frame, while *h* is being transferred from one to the other. The weights in the poise-frame on the left have a value of one hundred pounds, those on the next frame one thousand pounds, and on the last ten thousand, and the results

are read on the scale and by the figures shown in the slot adjoining.

The indicator-needle *F* constitutes the final lever of the scale, having a movement at the point of about two inches, and this movement is calculated to be three hundred thousand times greater than the movement of the piston *c* in the first hydraulic chamber, and in the largest sizes has been made to indicate six million times as much. That the machine does not suffer by repeated strains is shown by the fact that this needle returns to exact zero after every trial, whether strained in one direction by the compression of a piece, or in the other by rending a specimen in two. The machine, as now manufactured, is different in appearance

FIG. 96.



THE EMERY TESTING-MACHINE—TWO-HUNDRED-THOUSAND-POUND SIZE.

from the diagram just discussed. While the weighing mechanism is the same, it will be seen that the first hydraulic cylinder is laid on its side, so as to constitute a horizontal rather than a vertical machine. This change

affords certain advantages in overcoming the enormous shocks of recoil. In all but the smallest size of machine the weighing-head, shown on the left of illustration, and the straining-head, shown on the right, are made so as to rest on wrought-iron girders, or frames, along which they can slide without injury to anything. The machine here shown is of the two-hundred-thousand-pound class, and back of it, to the right of the weighing mechanism, is shown a pump for delivering the water-supply to the straining-head, which exerts the required force through the massive screws called straining-screws, that connect the heads.

In operation, for the purpose of insuring that everything about the hydraulic chamber has a solid bearing, it is necessary to produce an initial loading of about five per cent. of the maximum load, for which purpose springs are supplied to move the draw-bar in the direction in which the stress to be applied to the specimen will move it, and after this the scale is balanced by the sliding weights on the poise-beam. When a specimen breaks the blow is carried to the massive parts of the weighing-head, and is absorbed by them in such a manner as to protect the more delicate hydraulic supports, so that these machines can be used regularly for breaking high steel specimens up to their full capacity without risk of injury. The weighing-head is returned to its place on the bed after movement due to recoil by a set of spiral springs locked up in boxes secured to the bed. The specimens to be broken are held in dies that close upon them in such manner as to insure their protection against breakage in the part weakened by the cutting of the gripped part. When the specimen breaks it is always firmly held in the dies, so that there is no danger from flying pieces, which without such protection would be liable to scatter with terrific force. It is surprising to note that when rup-

ture occurs the only noticeable noise is that of the breaking piece, the machine readjusting itself and the parts sliding on the frame almost noiselessly.

The water for operating the straining-head is supplied from the pump through the jointed pipes that stand up high on the right of the machine. It will be seen that they are connected with the straining-head, and being arranged for either pressure or exhaust, their force may be exerted either in compression or tension, or, in simpler language, arranged so as to either push or pull.

The gearing on top of the straining head is designed for operation either by hand or power, moving the head either back or forth to accommodate the length of specimens.

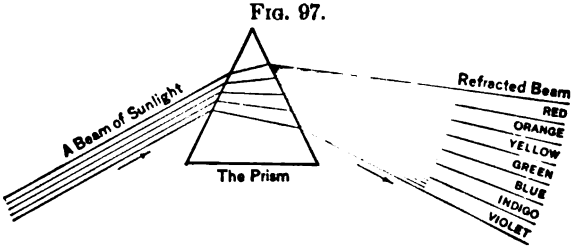
This machine is considered by engineers to have reached perfection in principle, and as marking an astonishing advance over former types. Its invention necessitated the construction of an exceedingly powerful and costly apparatus, constructed on somewhat similar lines, for calibrating the machines turned out and verifying by actual test the accuracy of each individual machine manufactured. This tester of testing-machines will indicate a variation of four ounces in half a million pounds. A weight of two hundred grains laid on the main platform of this remarkable machine is sufficient to put in motion material weighing more than twenty thousand pounds, as shown by a variation of the needle the fiftieth part of an inch, and the sensitiveness is the same whether loaded or not loaded.

THE SPECTROSCOPE.

A Wide-spread Field of Research opened up by an Instrument that was at first little understood.

To that wonderful instrument, the spectroscope, we owe nearly all the recent increase in knowledge of the stars. It tells us of what they are made, and the direction and speed in which they are journeying. Let us first consider what the instrument is, and then the principles on which it operates. In its simplest form it is a glass prism, through

FIG. 97.



METHOD OF OBTAINING A SPECTRUM.

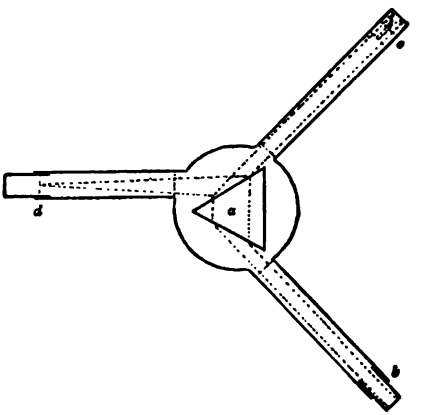
which a ray of light is allowed to shine. This prism disperses the light, giving the beautiful rainbow colors that children admire. These colors arrange themselves naturally in the order of red, orange, yellow, green, blue, and violet, and their graduations, and form what is called a spectrum. This spectrum is usually viewed through a magnifying eye-piece, like that of a telescope. There is also usually a minute scale, whose image is thrown upon the spectrum to enable the observer to measure it. Instead of the scale a fine wire or line of light from a slit may be moved over the spectrum, and by means of a micrometer-

screen the movement or distance of any point of the spectrum from any other can be read off. The tube through which the light enters should be a collimating tube—that is, a tube having glass lenses that cause the rays of light to enter in parallel lines. Instead of a simple prism, a train of prisms or a diffraction grating is commonly used in the body of the instrument. Such a grating may be one of two kinds—a transparent or transmission grating composed of glass, or a reflection grating made of brightly polished speculum metal. Upon one of these, extremely fine lines are ruled by means of a diamond point. To such perfection has the art of ruling these lines been brought that twenty-eight thousand eight hundred and seventy-six have been drawn within a single inch, this result being attained by Professor Rowland, of Baltimore. These minute rulings act as obstacles to the light, whether transmitted or reflected, and generate secondary waves, which by their interference produce a spectrum that has the advantage of having its different parts equally extended, which is not the case with refraction spectra, because the violet end of the spectrum obtained by a prism is more refracted than the red end, and as a consequence the violet rays are relatively more spread out, so that the amount of space occupied by these rays is out of proportion to the relative difference of their wave-length. This defect, which is termed the "irrationality" of the prismatic spectrum, is quite absent from that obtained by means of the diffraction grating, as the formation of the spectrum has been seen in the latter case to be solely dependent upon the different wave-lengths of the respective rays.

If a Rowland concave grating is used no observing telescope is required, a real image being formed that may be thrown on a screen or photographic plate.

In other instruments the telescope itself can be moved in the horizontal plane, and thus a fine wire across the occular can be brought into exact coincidence with any part of the spectrum, and the position may be seen by the amount of motion of the telescope, which can be read off

FIG. 98.



PRINCIPLE OF THE SPECTROSCOPE.—*a*, prism; *b*, telescope through which the light may pass; *c*, magnifying eye-piece; *d*, scale.

from a suitable scale on the stand. For astronomical use the spectroscope has a still different form, and is attachable to a telescope, through which the light of a star may be received.

Owing to the way in which the rays are turned aside from their path in the prism, the telescope and collimator in the ordinary forms of spectroscope must be placed at an angle to each other, but by an ingenious arrangement direct-vision spectroscopes are made that have the two tubes in line, so that they can be conveniently handled, or even carried in the pocket. This is possible because crown and flint glass differ in their power of refraction and dispersion.

The crown glass, being less dispersive, is used to bend back the slightly refracted and much-dispersed rays of the flint-glass prism, so that the central position of the dispersed ray comes to form a straight line with the incident ray of the collimator.

The first investigation into the spectrum of which we have record was conducted by Thomas Melvin, of Edinburgh, who published the result of his experiments in 1752, in a paper entitled "The Examination of Colored Flames by the Prism." After him came Wollaston, then Fraunhofer, and Sir John Herschel, each of whom added much to the world's knowledge of spectra. About 1830 the spectroscope was accepted as a useful instrument for detecting substances in flames and for analyzing solutions by noting their absorptive power on the light passing through them.

Every one of the chemical elements, as iron, lead, sodium, nitrogen, hydrogen, etc., when heated to a glowing gas or vapor emits a light that is different from every other element. The differences are not readily perceptible to the eye, but seen through the spectroscope they are clearly separated. Each element exhibits a series of bright narrow lines, always occupying certain definite positions, which are different for each element. Zinc, for instance, when vaporized and analyzed in the spectroscope exhibits three blue lines and one red line; copper presents three green lines; hydrogen gives double violet lines; iron presents an immense number of lines; and other metals have their lines, all of which fall in different places in the spectrum.

When a substance is heated red-hot it gives a continuous glowing spectrum, but, as soon as it vaporizes, the spectrum forms into lines. If several substances are mingled the

spectrum appears in the same manner, and if vaporized the substances under analysis will be revealed by their lines. Minute quantities that would evade observation in any ordinary analysis are readily found in this manner.

It was reserved for Kirchhoff, the renowned physicist of Heidelberg, to show to the world the real importance of the spectroscope, in 1859, by explaining the true significance of the relation of the bright bands of flames and the dark lines of the solar spectrum. He identified the dark lines at D in the sun's spectrum as identical with the bright lines of sodium. The lines were dark instead of bright because the strong light of the sun absorbed those rays with which the vapor would shine alone. It followed that if the sodium lines were recognized in the sun's spectrum, others might also be found. By investigating on this theory Kirchhoff by 1861 had identified sodium, iron, calcium, magnesium, nickel, barium, copper, zinc, and cobalt as existing in the sun.

Since Kirchhoff's time the examination of the solar spectrum has been extremely thorough, and nearly all of the seventy or more elements known on the earth are known to exist also in the sun. There have been found also two unknown elements, which have been named helium and coronium. Early in 1895, Lord Rayleigh, a British physicist, announced that he had found helium on the earth, in connection with a new gas, argon, previously discovered by him. His discovery of helium was very shortly confirmed by other physicists. Scientists are now in hopes that coronium will be found also. Thus was accomplished the wonderful result of finding a new substance ninety-five million miles away several years before it was discovered on this planet.

The spectroscope tells us that there are immense quan-

tities of iron in the sun, more than two thousand iron lines having been found in its spectrum. Sodium is also there in quantities. Hydrogen exists in the exterior, forming the gigantic red flames that astonished observers until they were understood. Calcium, the metallic base of limestone, is also present. All the familiar metals have been identified except gold. Perhaps there has been a corner in the sun's gold market for some years, and the yellow metal may be found later.

But the sun is only one of many stars, and each has a spectrum to be examined, and it is one of the astonishing features of this instrument that it is capable of receiving the very faint light that falls from a single distant star and separating it into a spectrum that may be read. In such work it is necessary to use a large lens to condense as many rays as possible. As the star appears only as a point of light, this involves the use of a cylindrical lens in order to spread out the rays into a line of light which can yield a spectrum having a visible breadth. On account of the feebleness of the light, very few prisms can be used in the train.

The stars are now undergoing classification according to their spectra, and those placed in the same class all have something in common. Those having very bright lines generally exhibit much hydrogen and helium. When the lines are bright instead of dark, as occasionally happens, it is thought that the vapors surrounding the star may be hotter than the interior, an anomalous condition of affairs that cannot be accounted for satisfactorily. One classification includes: First, a group in which the presence of metals is prominent. Our sun comes under this head, also Capella, the brightest star in Auriga. Second, the white or bluish-white group, which is the largest, including such

luminous stars as Sirius and Vega. These give a spectrum rich in blue rays, and marked by four dark lines due to hydrogen. They are believed to have dense atmospheres, under considerable pressure, and to be hotter and less dense than our sun.

The red and orange-colored stars form the third group, of which iron is a prominent constituent, and which exhibit absorptive atmospheres. They are believed to be astronomically old, and in a state of cooling, as their spectra resemble those of the sun's spots.

While learning the age and constituents of the stars by means of this wonderful spectroscope, that tells the tale over countless miles of space, by analyzing light-waves that have been years on their way, we gather yet more astonishing news from the observations. When a star is approaching or receding from us there is a marked shifting of the lines of the spectrum to one side. If the star's movement be towards us, the lines are shifted to the blue end of the spectrum; if away from us, to the red end. The amount of the shifting is the measure of the speed. Our eyes are so constituted that a certain number of vibrations of the ether per second are interpreted by the brain as a color, as red. Each color of the spectrum is the result of a corresponding number of vibrations per second of the wave-lengths of light. If a star is naturally of a green color, and if it neither approaches nor recedes from us, it will still appear green; but if it be coming towards us, the vibrations are altered and it grows blue. If the speed be still greater it is indigo, or if the velocity was enormous it would be violet. And if the star is receding it takes the color of the other half of the spectrum; if slowly, it grows yellowish; if much faster, orange; and if at marvellous speed, even red. Some stars are known in

this way to move at a rate of more than one hundred miles per second, and astronomers are satisfied that the possibility of error in these estimates is below five per cent. Argol, which is a very noticeable star in Perseus, has been called the Demon Star, because of its irregularities, visible to the naked eye. It retains a uniform lustre for two days and ten hours, as a star of the second magnitude, then it wanes and weakens to less than half of its former brightness; but after a period returns to its original lustre, only to repeat the performance as regularly as the sun rises. This puzzled astronomers until the spectroscope showed that during the bright period Argol moved towards us as rapidly as twenty-six miles a second, and during the dull period receded at a like speed. The explanation, then, is that Argol simply revolves in a small elliptical orbit.

The moon and planets, which shine by light reflected from the sun, return to our observation the solar spectrum modified more or less according as they have absorbent atmospheres. The moon's spectrum is precisely the same as the sun, which is one of the reasons for believing that the moon is entirely destitute of an atmosphere. The spectra of the largest planets convey to us a hint that they are still at comparatively high temperatures. Many nebulæ have been proved by the spectroscope to be principally gaseous in their formation, while the very diaphanous nuclei of comets are shown to be similarly formed. The spectra of comets' tails convey the information that they, like the planets, shine by reflected light.

Of all the inventions of the century the possibilities of the spectroscope are greatest and grandest. It has opened up entirely new fields of research for scientists. We can see the great suns hurrying hither and thither, on some divine plan that we have not yet fathomed. But the

spectroscope appears to be the key, and time and patience will give us the secret of motion of these mysterious orbs, just as we have learned of the motions of the system of planets of which our earth forms a part.

MISCELLANEOUS INVENTIONS

The Theatrophone, Convertible Theatre, Big Pleasure-Wheel, Rain-Making Appliances, Hydraulic Accumulators, Rope Machinery, and Minor Mechanisms.

THERE are very many more wonderful mechanisms than can be mentioned within the compass of this book. The ingenuity of mankind continues to prompt to new efforts, and the ideas of one inventor furnish food for another, so that the increase is constantly augmented. A few of these are briefly noted here by way of conclusion.

There exists in Paris a Theatrophone Company, whose name will suggest their business to any student of Greek. Since 1882 they have been connecting their patrons by telephone with the various theatres of the city, and their mechanism has been perfected so as to give a satisfactory service. The first experiment was made in 1881, twenty pairs of transmitters being placed on the stage of an opera-house, on either side of the prompter's box and in front of the footlights. A battery was connected, and double wires led to a line of receivers. Each receiver connected with a transmitter on the right of the stage and with another on the left of the stage, so that the listener could hear equally well, no matter on which side the action might be taking place. The result was so satisfactory that the above-named company was formed and the system developed. They now have a central office and seven radiating lines of

wires, to which are connected hotels, restaurants, and dwellings. A special room is provided for them in each of the theatres, with an attendant to see that all the transmitters are maintained in working order. At the central office are two young women—one to talk to subscribers who may desire to have this theatre or that one connected, and the other to make the connections and watch to see that all the lines are working properly. There are special contrivances for regularly verifying the condition of the lines. Between the acts the Theatrophone Company connects subscribers with music of its own production, so that something is to be heard the whole evening. By these means the company has maintained a reliable service, and secures good prices, varying according to the number of theatres connected. The receiving telephones are arranged for individual use like an ordinary telephone, or with a wide-mouthed funnel to disperse the sound so that several persons can hear at the same time. No doubt the company will shortly, if they have not already, add the kinetoscope in some manner to their service, so as to give a more perfect representation of the performances.

There is another novelty in the theatrical world that has just been added to the attractions in that progressive South American city, Buenos Ayres. It is a mammoth convertible theatre, which actually seats five thousand persons, and is provided with elevators to carry the patrons of boxes and galleries from the level of the street to any of the tiers above. By means of ingenious convertible mechanism the pit can be almost instantly transformed into a circus ring, a racing track, a ring for a bull fight, or a miniature lake for a swimming contest.

The enormous revolving pleasure-wheel built recently at Earl's Court, London, is most interesting from a me-

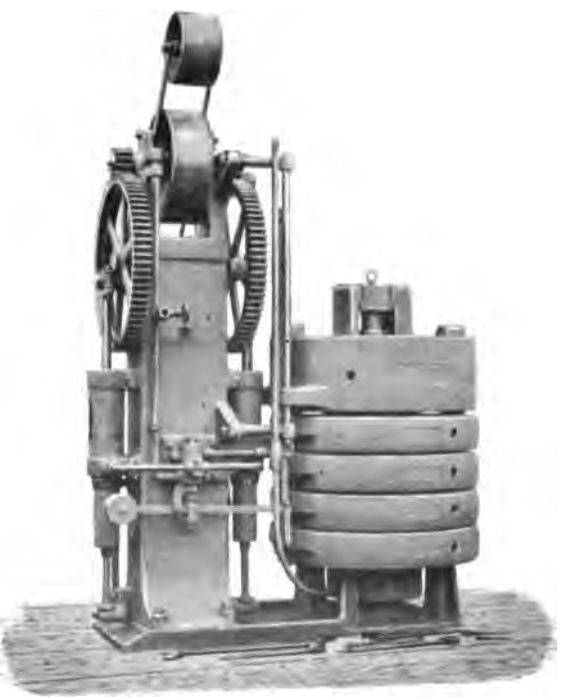
chanical point of view. It is three hundred feet high, and constructed of steel throughout. The axle is a steel tube seven feet in diameter, and thirty-five feet long, being made in three sections of one inch steel plates. There are forty passenger-cars, arranged as were the cars in the big Ferris wheel in Chicago. Each is twenty-four feet long, and seats thirty persons, so that the total number of persons who may ride at one time is twelve hundred. Ten of the cars are called first-class, and five of this ten are for smokers. Thirty are denominated second-class. The cars are loaded with passengers from eight levels near the ground, so that all the cars may be filled at five stoppages. The rotation of the wheel is accomplished by two endless chains, each over a thousand feet in length and of eight tons weight. These chains run in brackets on the extreme outer edge of the wheel-rim, and pass underground to driving pulleys. The power is obtained from two fifty-horse-power engines. On a level with the axle are two promenade saloons, reached by spiral stairs, and connected by a passageway leading right through the axle. Proper balance of the structure is maintained by the filling and emptying of water-tanks in the bottom of the passenger cars. The water is pumped up to the top of the columns, where are located storage-tanks, and the car-tanks are filled on the descending side. The erecting of the wheel involved a number of difficulties. The columns were first erected and the axle put in place. One of the forty sections of the wheel was then hung on, hauled to one side and the next one hung on. The work proceeded in this manner until one-half of the wheel was in place. The upper half had to be put on with the aid of scaffolding. There were no accidents during the erection, though a violent gale sprung up when the work was about half complete.

Rain-making is a business that has not received much sanction from scientists. Yet it is largely carried on in the Mississippi Valley, especially in the States of Kansas, Nebraska, Iowa, and Oklahoma Territory. The prairie settlers club together and hire some of the rival rain-makers to bedew their district for prices ranging from two hundred dollars cash to one hundred dollars down, and five hundred dollars more when the rain comes. The most conspicuous of the rain-makers carries his apparatus in three box-cars, locating one at each corner of a triangle of the district that is to be deluged. The cars contain water-tanks, gas-producing chemicals, and an electric battery, the duty of the latter being "to electrify the gases," whatever that may mean. For three days the rain-makers send off warm gas into the air, claiming that at a height of four thousand to eight thousand feet it turns cold, drops, and "causes a vacuum that attracts moisture and induces rain." As a high wind may blow it off to one side, the rain-makers are enabled to claim any rain that falls within three days within a radius of fifty or sixty miles. Of course this is wholly unscientific, but it pays. If the rain-makers would discover a way of sending very fine dust particles into the upper air, they might succeed in getting up a little shower occasionally, but even this method, which is based on scientific theory, remains to be proved as effective in practice.

In all hydraulic systems accumulators are requisite to meet sudden demands for extra power, and also for determining the pressure. In the Sellers hydraulic pump and accumulator, here shown, will be observed a series of heavy weights on the right. These are suspended on cross-pins when out of use, but may be thrown into action by pulling out the pins. The weights when in use rest upon the plunger in the hydraulic cylinder which they surround, and

their gravity is made to bear upon the column of water within, this in turn being connected with the tank at the left, where a pressure is kept up by means of the upright cylinder pumps. The weight used regulates the amount of the pressure in the tank, so that it may not alter with sudden changes in the work performed.

FIG. 99.



SELLERS'S HYDRAULIC ACCUMULATOR.

Within a few years the manufacture of rope has been entirely revolutionized, largely by one man, John Good, of New York City. He has caused the old rope-walk to be

superseded by automatic machines that manufacture the finest twine and the largest cable without hand labor. He has recently added to his other inventions an electric binding-twine spinner, that does about double or treble the work of the machines now in use. This will be introduced as soon as present patents expire. Good's rope-machine, as at present used, is really two separate machines, a former and a layer. The former has a circular gauge-plate, full of small holes, through which the threads from the bobbins are introduced. Thence they pass to a revolving horizontal capstan, which twists them into a cord that is gathered on a reel. These reels are taken to the layer, which is much larger than the forming-machine, and laid or twisted into a thick rope by means of a revolving capstan, similar to that of the former.

John A. Secor, an engineer of Brooklyn, New York, claims to have invented a practical method of vessel propulsion that will do away with steam-engines, screws, shafting, etc., on steamships, securing greater speed and increased room. His plan is a modification of the principle of the rocket, which is propelled by the gases that it shoots out backward. Mr. Secor proposes to use in a vessel a stout, cannon-like cylinder, extending lengthwise of the vessel and projecting into the water from the stern. From this cylinder or cannon he fires, at regular intervals, an explosive mixture of air and gas. This gas is manufactured from coal, and its explosion is managed as in a gas- or petroleum-engine. Mr. Secor has experimented with a vessel one hundred feet long, using a firing-cylinder ten feet long and eighteen inches in diameter. For a great ocean steamer he would use a battery of these firing-cylinders. His experiments and claims have attracted attention because of his standing as a mechanic, and because

of the success of motors made on similar principles, which are now coming into use for propelling bicycles and road-wagons.

It would be interesting to explore further, and note such interesting machines as the electric weed-killer, that may be attached to a locomotive and used to destroy the weeds growing on or near the track by the burning of a strong current; or the machine for dipping tin-plate, that handles three crates of plate at one time, picks them off the car, dips them in the molten tin, shaking them up and down a few dozen times, then lifts them out, into a cleansing or swilling tank, all automatically, by the power of steam; or the envelope-machine, that gathers in a roll of paper, some mucilage, and some green ink and turns out government envelopes all cut, gummed, stamped, and tied up in packs of twenty-five; or any one of a thousand others: but space forbids. We have gone far enough to gain a glimpse of what man is doing and is likely to do in the near future, and it is time to close the book.

FINIS.